

Science Still Born

The Rise and Impact
of the Pan American Scientific Congresses,
1898–1916



Rodrigo Fernos

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iUniverse, Inc.
New York Lincoln Shanghai

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iUniverse, Inc.

For information address:
iUniverse, Inc.
2021 Pine Lake Road, Suite 100
Lincoln, NE 68512
www.iuniverse.com

ISBN: 0-595-28424-8 (pbk)

ISBN: 0-595-74842-2 (cloth)

Printed in the United States of America

For my parents.

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Preface

“Nace ese deber de circunstancias especiales.”

—Dr. Pimentel,
Mexican delegate
2LASC (1901)

This is a story about the diffusion and the consequent development of science in Latin America. It is also about the international relations between the region and the United States, but less so.

While today we may take science for granted because it forms such a central part of our contemporary modern world—so much so that it is highly visible and thus easily criticized—science is a unique and distinctive worldview.¹ As the word suggests, it is a particular way of looking at reality, of focusing on certain aspects and not others. For example, it is materialist, but not in the sense most people usually take the word to mean. It does not refer to a self-centered egoism or a wealth-oriented perspective but rather to an orientation geared towards physical matter. Just as each individual has their own distinctive personality, each aspect of physical reality will also have their own unique make-up which natural philosophy, as it used to be more appropriately called, seeks to uncover. Science has other traits as well; it is experimentalist, empirical, mathematical, and mechanical. This being said, that science is a unique worldview will still not be as obvious or apparent at it might first sound.

A rather crude example might help—say a kitchen chair. We may all look at the object but how we understand that chair may vary greatly. Some might think of the memory of the grandfather who used to sit in it, others might consider how well it fits along with the house’s interior decoration, while others might look at its design and construction. Despite the fact that the chair remains the same, how we view it may obviously vary greatly from individual to individual or even across the many perspectives that arise within a lifetime. Similarly, how much meaning we give to it will also vary. We may walk all around it in the kitchen, focusing on a thousand other things except the chair that forms such an integral part of our life. We may think of the food we need to buy, of upcoming social events, or any given particular problem besetting us while we sit in the

kitchen chair. Yet how that chair affects our daily activities and how it invisibly shapes our Western world is rarely the focus of our attention. Until there is a subtle change—eating at a Japanese sushi restaurant for example—do we begin to become aware of our own invisible ethnocentric assumptions.

Such is not unlike the way the Latin American world, in the author's opinion, has traditionally viewed nature. Science has been not unlike Ralph Ellison's description of the downtrodden in North American society: ever-present but invisible. So too have been the men who have practiced it.

The scientific worldview is not "natural" to Latin America despite the fact that the region is culturally of Western origins. Although perhaps displaying virtuosity in the social realm, the Latin American has traditionally taken the realm of nature for granted. It was not something that could be moldable and changed towards the improvement of man's life, but rather something which was a given—rigid and unalterable under the glory of God. The author's place of origin, Puerto Rico, provides many subtle clues. The fatalistic attitude so common to older generations is perhaps the classic example of how the absence of this particular worldview shaped Latin American assumptions and helped define its own cultural identity. Similarly, since colonial art was mainly about political or religious figures in a somber indoor ambiance rather than in the background of an external natural environment also sheds much light on the foundations of the Latin American perspective. One only begins to see a notable difference in these paintings—the inclusion of the living green outdoors—at the beginning of this century with the end of Spanish colonialism. These and many other clues from other regions in Latin America form a coherent and uniform picture when considered in their totality.²

The author's own personal discovery of the scientific worldview was like a revelation. It is partly the realization that the world can be defined very differently in the most fundamental of ways—something difficult to describe unless one has actually experienced it. Traveling through hundreds of years of human thought paralleled the ontogeny-recapitulating-phylogeny paradigm, "en la mente." Not unlike anthropology, there is an inherent and fascinating relativism in man's constant quest for universal order. Perhaps more importantly, however, was the sudden awareness that one need not be eternally condemned to live with original sin, metaphorically speaking. In other words, the outcome of one's efforts will not be solely based on human frailty but rather on the exigencies and laws of the external world. A person may try with a religious-like diligence a particular task, but their understanding, or lack thereof, of the natural forces at hand will greatly affect their likelihood of success. Sheer strength, endurance, and fortitude—many of

the core components of machismo—were not enough. This intellectual experience of science through the eyes of its history can be rather liberating. It is a pity more students do not undergo this fixed journey.

Puerto Rico, however, is not the only one where we may get suggestive hints. North American observers of Cuban society also noted the puzzling effects of a non-scientific worldview at the turn of the century. The same assumptions about man can be unknowingly projected to the world around him. That the rope connecting the horse and cart was tied around the horse's neck, thus cutting and choking it, went entirely unnoticed by Cubans and had likely been practiced for centuries in the island. More cruel whippings apparently "fixed" the problem. A simple rearrangement of the rope would have not only helped the horse but would have made his labor much more efficient and effective. In these and many other aspects, Cubans initially resisted any suggested improvements to their daily lives, wrongly viewing them as agents of cultural imperialism—an argument uncritically accepted by too many historians. This is a good example of precisely why Western man places such a value on change, and more broadly, on progress. By carefully altering our world, we improve our lives. Ironically, Cubans would later accept "North Americanization" too blindly, destroying nature and their culture in the process of quick modernization according to some empathetic U.S. observers.³ They have not been the only ones.

As these examples illustrate, a rather unscientific worldview has plagued Latin America. It has helped give the region its own unique character, for good and ill. At the aggregate level, it can most obviously be seen in the small number of Nobel prizes given throughout the century, which can be counted with one hand. All of these were also from only one nation in the entire region: Argentina. Whatever the merits and fairness of this observation, it certainly points to a relative general deficit which is still true today.⁴ In the 1980's, worldwide surveys revealed that the scientific output was but a small fraction when compared to that of the United States, despite their similar geographic size.⁵ This difference in scientific output is at first somewhat surprising when one superficially looks at their urban centers. Certainly, São Paulo and New York City do not look all that different when seen from the air. Yet the numbers as to what actually goes on inside these cities cannot really be challenged as some Latin American historians have done, whether or not we agree with the assumption that Latin America should be more scientific than it actually is. Unfortunately, the failure to achieve a scientific ethos has also meant its economic stagnation. Its outward economic problems reflect in part internal "cultural" ones—at least *visa vie* other nations. We may point out that even though Germany was twice destroyed this century, it was able to

rebuild its economic “empire” because of its strong scientific culture. In contrast, Latin America’s problem has plagued it since its colonial days, keeping it backward financially. This is not to say that it has not tried to become more scientific, or rich.

As North America fully entered the Industrial Age in the second half of the nineteenth century, it became obvious to many Latin Americans that they had some catching up to do. The rise of August Comte’s positivist philosophy throughout much of Latin America at this time can be partly attributed to this desire for progress, irrespectively of whether it was appropriate for these ends.⁶ There eventually emerged a series of individual national scientific congresses, which ultimately were combined to form what is this book’s topic: the Pan American Scientific Congresses (PASCs).

By calling for the participation of the United States in 1908, the PASCs rapidly increased the process of scientific diffusion to Latin America at the turn of the century. If the Inquisition during the Colonial period had slowed down the transfer of ideas to a trickle, the PASCs would unleash the flow in a momentous torrent almost a hundred years after independence. Held about once every few years, they exponentially grew until seemingly reaching a certain critical momentum. Delegates across all the Americas attended these meetings, sharing what they had discovered, tested, or hypothesized. The intellectual stimulus was as dazzling as the new electric lights of the time. Although the congresses were not the only means by which scientific ideas were being diffused, they provided a direct link between science-rich nations and science-poor ones. The congresses’ potential for improving local science was of inestimable value.

Yet, given what we know of Latin American science in our time, why did the PASCs fail to successfully diffuse the scientific worldview to the region? Why did they not lead to a new era of Latin American prominence in science in the twentieth century? Again, the question is more perplexing than it might seem at first. While the delay of science during the Colonial period is easily understandable, it is less so during the twentieth century. Regions in Asia who were even more backward prior to the beginning of the century caught up much faster than did Latin America.⁷

During the colonial period, Spain’s arbitrary rule and backward scientific traditions afflicted the American south. If the United States inherited the British scientific outlook, her southern neighbor had similarly inherited her colonial parent’s perspective. Despite the strong tradition in natural history, which emerged during its colonial tutelage, it was not an intellectually dynamic process seeking or trying to invent new ideas in natural philosophy. We do not find the

likes of a Darwin looking to provide synthetic analyses for the accumulated data; we mostly find the mere accumulation of data. It is indeed curious to point out that it was observations made in South America by Darwin that provided the stimulus for his theory of evolution while other South Americans who had witnessed the same “data” had not come up with such ideas—and there were certainly many South American naturalists.⁸ Physics and other exact sciences were also relatively negligible. We should not be too harsh, however. As Thomas Glick points out, science seems to have actually improved somewhat towards the end of the eighteenth century until the period of independence. The revolution, however, was terrible for the development of its science. Many would-be scientists were killed, infrastructures remained undeveloped, and all the vagaries of political turmoil did a great deal of harm to its scientific growth.⁹

As we enter the twentieth century, however, there was a change; a new helping hand had appeared. The United States had now become, or certainly was in the process of becoming, a global power. Although keeping her long-cherished isolationist stance, she became increasingly entangled in world affairs, out of both self-interest and social responsibility. Throughout the century, the U.S. repeatedly sought to help Latin America “lift herself by her bootstraps” as it was called in Puerto Rico by encouraging its scientific and technological development. The PASCs were one such effort which long predated Kennedy’s failed Alliance for Progress or Truman’s more global Point Four program. For example, one of the Alliance’s programs first initiated at the PASCs had been the exchange of university scholars and students between the two regions. Unfortunately, despite these many other varied efforts, it has been acknowledged that they have not always been successful. As such, Kennedy’s programs had long and ample precedents.¹⁰

Can the PASCs be used to identify long-term internal hindrances to scientific development in the region? Why has the diffusion of science to the region been beset by so many delays?

The Pan American Scientific Congresses (PASCs) are an excellent subject in that they provide a great deal of data that otherwise would not be found in more specialized case studies. Spanning over half a century, they enable us to plot the advancement of science in Latin America between the Spanish-American War and W.W.II. One is able to see when a particular Western (European or North American) idea was introduced, and how exactly it flourished on the local soil. Although there were gaps, as in most kinds of historical records (written or non-written), we can easily fill some of these in by using well-documented studies in the history of science. One should also note that there are intrinsic factors to scientific advancement that provide it a great deal of coherence, and which conse-

quently can also be used by the historian as cognitive guides irrespective of the documentation at hand. In sharp contrast to many other types of histories, there is a certain “path dependency” to science.¹¹

Yet, we even need not rely on a consecutive number of congresses to trace such changes. Any one particular congress will just as easily reveal developments of antecedent diffusions as well as the direct introduction of any one particular idea. Knowing that something new is discussed that was not discussed previously is an indication of the changes, which occurred between consecutive congresses. Similarly, the lack or presence of continuity of any one particular topic throughout the congresses helps inform as to what the leading questions of the day were, or even if such heuristic paradigms existed at all. Since the congresses were essentially dialogues between scientists, the topic also gives us some insight into the social coherence and personal opinions of the regional scientific community. Given the prominence accorded to such congresses, we are also observing the best science that Latin America had to offer. Their international nature meant that they were no mean small affairs, but were rather displays of scientific prowess. It is as if one could not possibly ask for anything better to answer our query.

The book focuses on two particular areas: physics and chemistry.¹² Although the turn of the century was marked by many scientific revolutions, these two were perhaps the most important not only because of their intrinsic intellectual merit, but also because of their deep ties to the economy. Consequently, they help broaden the context by bringing in factors seldom touched by works as those specifically dealing with biology. As such, they provide contrasting counterpoints to the science-economy interactions as those described by Safford of the Colonial period.¹³ Although much had changed, there were continuing patterns; *la longue duree* of history has been rather persistent. That the two topics are also so influenced by technology, and each other influence technology, means that their inclusion also helps elucidate the engines of economic progress in the region.

There are two primary factors the book addresses: the influence of culture and the economy. To what extent did they inhibit or stimulate scientific progress in the region? Again, their influence is not what we might think it is.

While preparing an article for a Mexican-American gazette, the author once interviewed Juan Sanchez, an Argentinean who was then the interim-Vice President of Research at the University of Texas (Austin). The author asked him for his opinion as to the slow growth of Latin American science. To him the issue was rather simple: money—or more precisely, the lack of it. The shortages of funds in the region meant that it could not compete on big projects with her Western counterparts, and thus contribute new ideas—a valid point in today’s

era of big science. He was right in that the construction of a fifteen story-high underground pool to detect a few barely discernible neutrons, as Japan recently completed, would be an extraneous project entirely out of the question. When asked whether culture had anything to do with its stagnation, Mr. Sanchez dismissed the suggestion offhand. One could hear him internally murmur, "What a ridiculous question!", and not without some merit. As William McNeil wrote in the *Rise of the West*, one cannot account for historical outcomes based on such broad phenomena as "culture". There would be no need for historical actors, human will, or events themselves; humans are not blind machines.

Certainly, to imply that culture has hindered Latin American science is not to not suggest that Latin Americans are inherently poor in science. In contrast to North American traditional reserve, Latin Americans are more open to express their fair ideas and sensitive opinions—showing a certain amount of greater oral intellectual vitality. If intellectual progress depends on this type of exchange, then the grounds are certainly there. The author, as a student, encountered something similar while once living with Egyptian students who had been rather disappointed with the intellectual culture common across U.S. universities. They expected to find wisdom when they arrived, but instead found rather hollow and empty comments and conversations; it was not the land of "wealth" they believed it was. Indeed, our own debates and arguments were personally enriching, and demonstrated a rich Middle Eastern intellectual culture that is seldom given credit to in the United States. Instead of that idle talk in vacuous ideas not personally believed, discussions centered on genuine questions, insightful observation, and honest acknowledgment. Certainly, this does not form the core of science, but without these subjective traits, the experience of science would certainly not exist. The U.S. has in fact been declining in terms of the science natively produced despite the overall increase during the last two decades.

What was being suggested to Mr. Sanchez is that culture plays a role far more elusive and complex than is generally recognized. Because the scientist himself is not encouraged to write at length of his personal experiences, or perhaps that he may be fully aware of the factors influencing him, this data is not readily available. Yet, it is even worse for the Latin American scientist who rarely, if ever, wrote personal memoirs perhaps because he had not achieved much in terms of world recognition. While there are few records for the thousands of scientists that participated in local scientific congresses, there exists a tremendous amount of data for members of similar European and North American meetings. That stimulus which is created by a world-wide audience is obviously not felt by "third world" scientists, and hence their personal experiences are much more likely to be

forgotten with the passage of time. Science's universalism ironically tends to drive to oblivion those who do not make their mark. Obviously, however, it need not meant that they were any less important from a regional point of view.

This book hopes to elucidate that invisibility which the Latin American scientist of day yonder experienced and failed to entirely record.

Acknowledgments

First, the author would like to thank the staff at the Benson Latin American Collection at the University of Texas in Austin. Historians would not exist without their primary sources, and these sources would not exist without the delicate care of librarians. The staff was very kind and helpful in their careful balancing of access versus preservation. The institution is an invaluable resource to all Latin Americans, despite its relatively small size in comparison to major U.S. libraries. The staff at the various University of Puerto Rico system libraries was also very helpful in identifying some secondary sources—even if sometimes these could be found nowhere on the stacks. It is rather unpardonable that the island's scarce bibliographic resources are not more valued by the student community. Many don't realize that, although local libraries are indeed small by U.S. standards, they have a great deal more resources than many other educational institutions in Africa, the Caribbean, and Latin America.

Some individuals were particularly helpful in the book's creation and completion. The author is grateful to the J.B. Neilands and Tor Neilands at Berkeley for their helpful editorial comments on earlier versions of this work. The wonderful Michelle Mayfield also took time from her profession in "Maxwellian" home economics to do some very valuable proofreading. Joseph McElrath helped fill in some of the details by doing post-research research when the author was unable to do so. A class "Colonial Science" with Roderick Home, a knowledgeable Australian historian of science, laid the historiographical foundations of this book. The author is indebted to Professor John Eyler and Bruce Hunt for carefully balancing the delicate requirements between intellectual rigor and psychological sensitivity in our many chats during graduate school. The author would also like to thank that very well known and often-quoted historian of technology, Edwin Layton. He had absolutely nothing to do with this book—except perhaps by those few important "lessons" taught in his difficult-but-wonderful graduate seminars. A word of appreciation is extended to Prof. Alfredo Torruella Sr., physics professor at the University of Puerto Rico. His kind invitations to colloquiums at the university here brought a welcome collegiate stimulus while writing the book.

Lastly, the author would like to especially thank his parents, Gonzalo Fernos Lopez and Patricia Roane Riddick. Perhaps the fact that one is Latin American

and the other North American, and each very much so, influences the tone of this work. Without their support, this book would never have been completed.

R.F.
San Juan, Puerto Rico
May 21, 2000

1

Root's Dream:



The Pan American Scientific Congresses and The Decline of Science in Latin America

"Truth recognizes no national boundaries."

—President Woodrow Wilson

We should not be deceived, not even by ourselves. The Second Pan American Scientific Congress (2PASC) was really the fifth in a series of scientific gatherings held by Latin American nations, but the first to have been hosted by the United States. If many of the previous congresses were meant to internally stimulate the emerging scientific expertise of Hispanic American nations, this particular congress was meant to share the "great sister to the north's" already attained scientific and technological achievements with her southern neighbors. Perhaps more importantly to its host, however, was the fact that since it was held at the beginning of W.W.I, the 2PASC was also meant to unify the vast gaps of understanding between the America's two cultures: those of British and Iberian origins. Only through science, it was believed, could genuine Pan-Americanism be achieved.



Figure 1: Inaugural opening session of the 2PASC¹⁴

Held in Washington D.C. during the Christmas of 1915, it had 2,238 attendees, representing 21 nations, 650 universities, and 350 scientific and commercial bodies in the U.S. and Latin America; about 1,000 papers were presented in it.¹⁵ This number surpassed all previous Latin American congresses, and it would not be exceeded in future congresses. Only individuals authorized or recommended by respective governments were invited to serve as delegates. It was also attended by the ambassadors and diplomats of all southern nations as well as leading U.S. governmental leaders, which included Secretary of State Robert Lansing and U.S. Vice President Thomas R. Marshall. On the last day of the congress, President Wilson addressed its delegates. So great was the demand for attendance to that lecture, that its venue had to be relocated from the smaller Pan American Union Building to the more ample Memorial Continental Hall. Even William Jennings Bryan would have his say at one meeting or other during its proceedings.

The Congress was divided into 9 sections ranging across almost all scholarly disciplines.¹⁶ Although it was not strictly “scientific” in the sense that its topics dealt only with the natural world, it is hard to imagine such a vast-ranging congress being held today. Leading men of North American science attending 2PASC included: Elmer Sperry (inventor of the gyroscope), C. D. Perrine and Frederick Sears (astronomers), William C. Gorgas (participated in discovery of the cause of yellow fever), William H. Welch (revolutionized medical education), A. L. Kroeber and F. Boas (well known anthropologists), Hiram Bingham (dis-

coverer of Machu Picchu), W. H. Holmes (head curator at the Smithsonian Institution), and others.

The U.S. Congress set aside \$85,000 for its organization while the Carnegie Foundation donated \$100,000 to transport and house a third of the delegates to the congress. Typical of its era, private philanthropy would continue to exercise a leading role in the stimulation of science early this century—a task which the national government would not seriously take up until the Second World War.

Charles Davenport clearly demonstrated 2PASC's well-recognized contemporary importance in *The Outlook*

But it was much more than that [a scientific congress].... it was a political congress of vast significance. Hundreds of selected representatives...educators, scientists, officials, talked together, walked together, ate together, thought together, for two precious weeks of the world's history....[It had] a seriousness of purpose and an earnestness of international conviction which will render it permanently notable in the history of the Western hemisphere.¹⁷

The opening ceremony and consequent events displayed the solemnity of the occasion. Held at the Continental Memorial Hall at 10:30 am on December 27 in the presence of U.S. Navy, Marine Corps, and Army guards with the flags of all American nations serving as backdrop, John Barrett, Secretary General of the Pan American Union, was the first to speak. He was followed by the President of the Congress, Don Eduardo Suarez Mujica (Chile), and later by Lansing and Marshall. Thereafter, a chorus of 125 sang the Pan American Hymn, followed by a long bout of applause.

Washington D.C. opened itself to the event. Most of the sessions were held at various local hotels in which the delegates themselves resided—section three was held at the Oak Room of the Raleigh hotel; section six at the lounge of the Shoreham, and section nine at the Small Ballroom of the Willard. In contrast to the previous congresses, there was a rather democratic element to its organization in that most dinners were decentralized and held for respective groups in private homes. For example, on the 28th of December some members went to 800 Sixteenth St. for a dinner held by Sen. & Mrs. James W. Wadsworth while others went to 2012 Mass. Ave. for another held by Mrs. Samuel Spencer. Prominent governmental leaders also gave dinners that same day, such as that hosted at 1515 Massachusetts Ave by Charles S. Hamlin, Governor of the Federal Reserve Board, or at 1607 H Street by the Commissioner of Patents, Thomas Ewing.¹⁸ Some believed it was unusual for U.S. members to accept into their homes visiting delegates. "Never before had this been done to any such extent in any interna-

tional gathering, and it naturally had the effect of bringing visitors into closer and more cordial relations with each other as well as with their heroes in the United States.”¹⁹

President Wilson held the last dinner at the White House. It is curious to mention that since all had been invited there was not enough space; the food line stretched through the Blue Room, down the grand staircase, and into the Treasury entrance two hours after they began serving the meal. President Wilson stood in front of the White House, shaking all of the delegate’s hands as they entered his abode, which must have been quite a feat in and of itself.²⁰

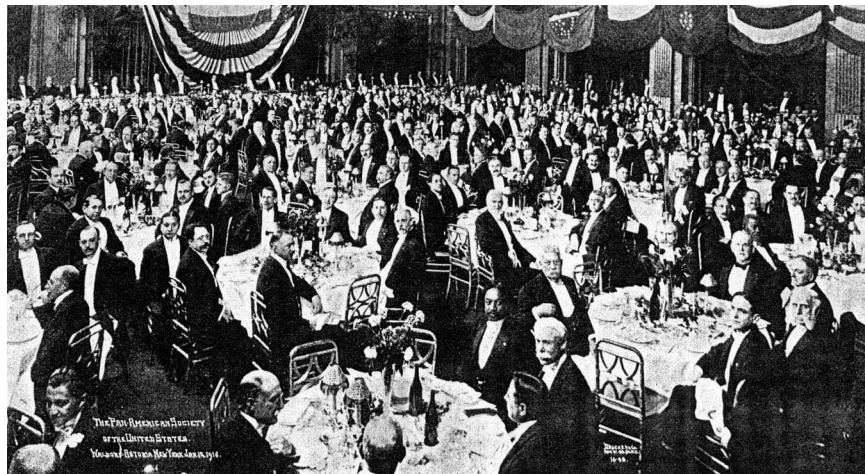


Figure 2: Banquet on January 12, 1916.²¹

A number of social events had been planned throughout the Congress to further bring the two continents together. During the last day, bronze and silver medals were distributed to the corresponding delegates. On these were imprinted, “Friendship-Solidarity-Progress Through Scientific Achievement”, with two North/South American figures clasping hands. A number of “smokers” were given in the evenings—gentlemen’s social gatherings held at the Cosmos Club. There was an “air show” by Juan Domenjoz, who did “loop de loops” in front of the Pan American Union Building on Jan. 4. New Year’s Eve was inaugurated by a gala at the National Theater, followed by celebrations at the Willard Hotel. Since their wives had accompanied the majority of the delegates, there was ample dancing and other non-scientific enterprises. U.S. citizens hosted almost all of the social events. The only exception seems to have been one held by the

Chilean delegation at their embassy at 1013 16th St. on Dec. 29. More scientific “extra-curricular” activities included lectures by W. W. Campbell, then president of the American Association of Science (AAAS) and director of the Lick Observatory, on the stars of the southern hemisphere; movies about the U.S. manufacture of common goods such as glass and cement were also shown during the proceedings.²²

After the Second Pan American Congress ended, its delegates were invited to visit leading U.S. universities from January 10 through the 16th. These included Johns Hopkins, Pennsylvania, Princeton, Columbia, Yale, and Harvard. Alberto Gutierrez, a delegate from Bolivia who had gone on this trip, reported to his government that U.S. universities were characterized by equality; there was little of that class hierarchy which pervaded Latin American universities. Although a certain hierarchy certainly did exist, it was based mainly on personal achievement—it was meritocratic rather than nepotistic. Johns Hopkins was particularly one of the “mas modernas e importantes en la Union.”²³ A special post-congress dinner was also arranged at the Waldorf Astoria on January 12 with a select list of 600 guests to thank them for their attendance. And with due reason.



The Pan American Congresses as 2PASC ushered a new era in U.S.-Latin American scientific relations. The first PASC was held in Chile (1908), while the Eighth American Scientific Congress held in 1940 seems to have been the last of its kind. These PASCs stimulated the rapid growth of more specialized inter-American scientific congresses in the post W.W.I era, thereby promoting the diffusion of science from science-rich countries to science-poor ones. These inter-American congresses included: First Pan American Aeronautic Conference (1916), Inter-American Electrical Communications Conference (1924), First Pan American Convention of Engineers (1929), First Congress of the Pan American Medical Association (1929), First Inter-American Radio Conference (1937), South American Botanical Congress (1938), Inter-American Conference on Agriculture (1940), and so on.²⁴ More specialized congresses, both pan-American and Latin American, have continued to increasingly proliferate in recent decades.²⁵ It is somewhat hard to believe that these congresses have seldom been given the scholarly scrutiny they deserve, either by historians of Latin America or historians of science.²⁶

Figure 3: Executive Committee²⁷

Although the U.S. was to gain a dominant position later in the congresses' history, the inter-American scientific meetings were not of North American origin but rather stemmed from its southern counterpart. The PASCs had been formed out of a series of scientific conferences mainly limited to Latin American participation at capital cities: the 1LASC (1898) in Buenos Aires, the 2LASC (1901) in Montevideo, and the 3LASC (1905) in Rio de Janeiro. There was an overlap in 1908 between these congresses in the first LASC, which had also been called the First Pan-American Scientific Congress (4LASC/1PASC), and was held in Santiago. It had then been decided to widen the national scope of participation, but not necessarily only to include the United States as a member nation. The first four LASCs had mainly been a Southern cone phenomenon; Argentina, Uruguay, Brazil, and Chile respectively served as host countries. Although Caribbean core states, including Venezuela and Mexico, would participate, their involvement had been relatively insignificant in these earlier congresses—a point well recognized by Chileans during the planning of 4LASC/1PASC.²⁸ Thus, the first PASC sought to be a genuinely all-inclusive American phenomenon by purposefully avoiding the mistakes of its predecessors: Mexico and the United States would be well represented in it. Congresses held after W.W. I would eventually drop the “Pan” or “Inter” from their official title. These American Scientific Congresses were held respectively in Lima (1924), Mexico City (1932), and again in the United States (1940).²⁹



Figure 4: Mexican delegation³⁰

The LASCs, PASCs, and ASCs in turn emerged out of a growing body and interactions amongst native scientists in the southern core states. By 1898, for example, five national scientific congresses had already been organized in Chile. Yet formal credit for the broader movement as a whole, the PASCs, is usually attributed to Argentina, which created the first congress in 1898.³¹ For its 25-year celebration, the Sociedad Científica Argentina had decided to invite other nations to participate in an all-inclusive Latin American congress. That the *sociedad* had such a history is also indicative of the emerging Latin American scientific organizations towards the last quarter of the nineteenth century. This increase in the amount of local scientific activity seems to have provided the initial demand for a more diversified set of contacts and scientific interactions, which themselves further broadened in scope as the national congresses proceeded. One exception was Mexico, where the relation between the “global” and the “local” was reversed. It would not form its first national scientific congress until 1912, long after the PASC’s and LASC had been created.³² While some Latin American scientists had participated in European congresses, they seem to have been relatively rare.³³

A historical truism, the earliest congresses produced the least amount of sources on which the historian can draw on. As the importance and size of the

congresses grew, so did the respective amount of information available about them.

Although the total number of official delegates was much smaller than the total number of participants during the 1LASC, Southern core nations (Argentina, Uruguay, and Chile) provided most of the 526 participants. The official roster was as followed: 8 from Argentina, 8 from Uruguay, 8 from Chile, 4 from Peru, 3 from Ecuador, 3 from Mexico, 1 from Paraguay, 2 from Venezuela-2. We may also note that, in contrast to later LASCs, it was more strictly scientific as well—only 23 papers (20%) were given in the social sciences, while natural sciences and medicine accounted for 88 of the 111 total papers given.³⁴

Country	1CCLA	2CCLA	3CCLA	1CCPA
Argentina	8 (19%)	126	74	377
Bolivia	—	—	5	52
Brazil	—	16	474 (68%)	51
Chile	8	40	13	1,119 (59%)
Colombia	—	—	7	7
Costa Rica	—	—	3	—
Cuba	—	—	2	5
El Salvador	—	—	1	2
Ecuador	3	2	4	5
Guatemala	—	1	3	19
Haiti	—	—	1	4
Honduras	—	1	2	2
Mexico	3	2	5	32
Nicaragua	—	—	2	1
Panama	—	—	—	4
Paraguay	1	3	8	4
Peru	8	7	11	63
San. Dom.	—	—	—	2
E.U.	—	—	—	55
Uruguay	8	536 (73%)	80	31
Venezuela	2	—	2	1
Total	41	734	697	1,899

Table 1: Distribution of official delegates by nationality

Whether the perception was valid or not, the 1LASC in its time was defined as a tremendous success, thus further stimulating the formation and growth of consequent congresses. It had been an important first step in the development of Latin American science. According to the Secretary General of 4LASC Eduardo Poirier, the growth of the congresses was as follows: 1st: 552 attendees, 121 papers presented; 2nd: 839 attendees, 202 papers given; 3rd: 863 attendees, 120 papers given; 4th: 2,238 delegates, and 742 papers given.³⁵ The privilege and sig-

nificance of hosting a congress was so increasingly important, that there was a consequent increase in the conflict between the delegates for this honor.

The Second Latin American Scientific Congress was held at Montevideo, Uruguay. As in the previous congress, the smaller number of official delegates came from Southern core countries, Argentina making the top of the foreign list with 37 official delegates, followed by 4 from Chile. A random sampling, however, reveals that Uruguay provided by far the largest number of representatives: about 70%.³⁶ Institutionally it had 28 representatives as opposed to Argentina's 20. One should note that the total number of papers allotted to the natural sciences began to decrease, as the number of papers in the social sciences increased to half of the total 209 papers. By contrast, there were 21 papers in basic sciences and 93 papers in applied sciences (including medicine, which was the largest section)³⁷

This pattern was continued in the next two congresses. The host nation, in particular the capital city, usually provided the largest number of participants, while the percentage allotted to natural science in the "scientific congresses" gradually declined. The Brazilians had taken the largest percentage of total delegates, 68% out of 697 during 3LASC, while the Chileans, providing only half, seem to have outdone them by flooding the 1PASC with 1,119 native delegates. Inversely, the percentage of papers dedicated to basic science continued to decline, going from 20% in 3LASC, to 15% in 1PASC, to 7% in 2PASC. Paul Reinsch, U.S. delegate, believed the social sciences section in the 1PASC had been "somewhat overcrowded with materials," and also that the congress had included too great a number of non-scientific fields such as art, literature, and so forth.³⁸

It is important to note that although the emerging revolution in physics had been given some treatment in the earlier congresses, it completely disappeared by 2PASC. Although quantum mechanics would not be developed until the mid 1920's, signs of the problems with classical mechanics and the likelihood of a new physics had already emerged more than a decade earlier. For example, Roentgen had discovered x-rays in 1895, Planck had introduced concept of quanta in 1900, Einstein's now-famous articles in the *Annalen der Physik* appeared in 1905 and, by 1913, Bohr had published his model of the hydrogen atom. A European conference dedicated specifically to quantum phenomena had been formed as early as 1911—one in which Henri Poincare had accurately alluded to its potential revolutionary consequences.³⁹ Thus it is very surprising that the topic was not included at all in the 2PASC's 1915 agenda—even more so when we consider the intellectual proximity of U.S. scientists to their European colleagues. Robert Mil-

likan, seeking to disprove some of Einstein's theories, actually ended up providing their experimental verification by 1910 at the University of Chicago. One should remember that the 2PASC was hosted and organized by the United States, not by a Latin American nation.

While it may be pointed out that the total number of scientific papers increased throughout the congresses, it is fair to say that the scientific character of the congresses as a whole had declined. The actual number of papers in basic sciences remained surprisingly minuscule, growing only from 23 in the 1LASC to 68 by 2PASC, despite the tremendous overall growth of the congresses themselves.⁴⁰ This emerging gap, and the increasingly incongruous relation between the scientific congress's official title and its actual role, is highly unusual. The congresses, despite increasing U.S. involvement, did not retain their integrity, either of purpose or of representation. The main emphasis had shifted from the basic science of the natural world to the applications of the social sciences. This change can also be observed throughout the organizational changes of the sections in the various congresses. With time, more subdivisions were created within the social sciences than the natural sciences as the congresses developed, hence allowing for a greater number of participants in these fields.⁴¹ Given its strong literary traditions, the Pan-American scientific congresses had become distinctly Latin American.

The shift in emphasis from scientific concerns per se to non-scientific ones had become increasingly obvious. Reinsch commented that the 1PASC had been "imprest with a semi-public character." Not only had the president and public ministers taken part as officers in sub committees, but also foreign diplomats had been as prominent as the scientific representatives themselves had. By the 2PASC, this prominence had become so obnoxious that even Secretary of State Lansing had suggested dropping the word "science" from its title. A writer for *Scientific American* magazine harshly complained about this extra scientific influence in April 1916. "Many scientific men who attended the congress gained the impression that the meeting was primarily a political rather than a scientific one; and it is undoubtedly true that the political aspects of the congress overshadowed everything else." The author also criticized that it had been very poorly planned as it coincided with the annual meeting of the AAAS, thus preventing the most distinguished North American scientists from attending.⁴²

Thus the total scientific benefit, which could have been derived from the congresses, was drastically reduced due to this emerging shift, thereby greatly undermining the purposes of the congresses. The reduced emphasis on basic science meant that the transfer of knowledge would occur at a much slower rate than it

could have occurred. Had all of the thousand papers presented been in the basic sciences, a significantly faster diffusion would have proceeded, and perhaps the congresses would have given Latin America that which later efforts, as Truman's Point Four program or Kennedy's Alliance for Progress, tried to provide but didn't: the key to modernity.

It is of some doubt whether the Latin American scientific community would have been open to this "downloading" of scientific expertise. We need not assume that it could have proceeded any faster. Had it been a simple question of information transfer, the process most likely could have occurred relatively easily; but, since more complex dynamics pertaining to paradigm changes needed to have occurred, the process was naturally slowed down. This delay would have also compounded the case if both the provider and receiver were not aware of the full range of factors affecting the process; that is to say, if they had both believed the problem to be merely one of information transfer. Metaphorically speaking, it was not just the connection (human interaction via congresses), which needed to be expanded, but the internal hardware (scientific mentality), which needed to be upgraded as well. Such is a much more complex social process than the installation of memory chips in a computer. This issue, however, will be treated later.

Dependency theorists argue economic ties between peripheral and core states actually serve to weaken the periphery to the benefit of the core. Rather than creating a broader market in which each nation can specialize in a limited number of goods to thereby produce these much more efficiently, the international system so ardently supported by John Stuart Mill was actually parasitic. As Raul Prebisch pointed out, the prices of industrial goods constantly increased at a stable rate, while the price of primary goods radically fluctuated in a downward trend. Economics under these circumstances was zero sum in sharp contrast to the claims of laissez-faire theorists; one nation gradually gained at the expense of another's loss.⁴³

Given the decline of scientific output throughout the Pan American scientific congresses, could the same claim be made with regard to US-LA scientific relations that dependency theorists have made for their economic relations? In other words, was the United States using these scientific congresses as a pretext to strengthen its increasing hegemony over the region by weakening Latin America's scientific base? Was this just another case of cultural imperialism? Because the fields are so different, science and economics, how could such an argument be validly structured?

It seems that there would be two interrelated aspects to such a claim, the first of which has already been pointed out. They are as follow:

Firstly, contrary to what might appear to be the case, closer scientific association actually hindered nascent Latin American scientific growth. Had the Latin American Scientific Congresses (LASCs) remained distinctly Latin American, the region's scientific progress would have occurred at a faster pace than it actually did. The U.S. entry, however, disrupted this "natural" process out of self-interest. U.S. delegates were well aware of the significant role of science by 2PASC, referring to W.W.I as the "chemists war"—hence all the more reason to hinder the rise of a potential enemy by denying him the sources of national power.⁴⁴ The deterioration could be observed not only in the actual scientific content but also in public support of science—the "murder" of Latin American science was both organizational and rhetorical. This scientific decline coincided with the rise of pan-Americanism; correlation in this case is equal to causation.

Secondly, it might also be argued that science was used as a pretext to exert greater political influence over Latin American nations. Several U.S. leaders complained that because the Pan American Congresses (PAC, not PASC) were too strictly focused on political and diplomatic issues, they ironically tended to have a small effect on U.S.-LA relations. Fearing the worst, foreign attendees were too reserved, thereby inhibiting any sort of hegemonic influence by U.S. participants. In the PASCs, however, because scientific exchanges required open and honest debate as a prerequisite to any significant progress, delegates in these congresses were much more amenable to manipulation. Since they candidly expressed their views, any worries could at least be addressed. Science was thus used as a backdoor to political influence.⁴⁵

Similarly, it could be argued that because the congress's spectrum increased in breadth, U.S. representatives were more able to introduce measures for their own benefit which would not likely have appeared in a congress that was more strictly "scientific", in other words those congresses dealing solely with issues about the natural world rather than human relations as the PASCs did. During a time when capitalism's development required a series of world wars to assure its expansion, the scientific congresses helped assuage objections by the Latin American community to such wars by establishing closer ties.

There is some merit to these observations.

The U.S. monopolized both the content and context of the congresses. The 2PASC should have actually been held in Lima, but by exerting political influence, U.S. representatives were able to manipulate the selection towards Washington D.C., perhaps not unlike recent Olympic committee fiascos. Lima's opportunity would have to wait a little under two decades.⁴⁶ In addition, while the first triage of distinctly Latin American congresses had been held during the

summer, the entrance of the North Americans forced a shift in the time of these meetings to the wintertime. This was the case even though the congresses were not held in North America (1PASC).⁴⁷ It should perhaps be noted that while the social events at any one of the particular Latin American congresses were hosted by various non-hosting nations, North Americans tended to monopolize these gatherings during their tenure. The U.S. also greatly delayed the proceedings when it first became host, holding the 2PASC in 1916—four years after it had agreed to do so at the end of the previous congress in 1908. This time lag between the two congresses, the 1PASC and the 2PASC, was almost as great as the age of the congresses themselves. Oddly, science received the least attention in the congress most widely covered by the media, the 2PASC. Almost all of the articles of the *Daily Bulletin*, or *Boletín Diario*, a newspaper specifically formed to describe the proceedings and events, were of a non-scientific nature.⁴⁸

Yet, more substantive examples of undue U.S. influence can be provided as well. In a congress supposed to be of a purely scientific nature, the 1PASC, two thousand delegates voted in support of the Panama Canal. Other resolutions included laws guaranteeing capital stock and the study of “how to create in the American countries a correct system of...credit”.⁴⁹ Elihu Root, who had represented corporations early in his legal career, unduly influenced its delegates to form the American Institute of International Law in the following congress. This organization sought to impose a hegemonic order into the commercial relations by standardizing their legal affairs. Rather than each nation operating under its own sovereignty, it would have to abide by “common mutual agreement”—agreements which, according to some historians, by default were more heavily influenced by powerful nations than weaker ones. In addition, by creating a more reliable and stable legal environment, the Institute sought to guarantee the expansion of North American businesses into Latin America. As William Shepherd has shown, Latin American trade with U.S. was abysmally low by the turn of the century. Only a quarter of Latin America’s \$2 billion trade was with U.S.; even then, the U.S. had a trade deficit of \$70 million. It might be argued that Root, despite all claims to creating a more just social order, really sought to lend a hand to the corporate world he had previously represented.⁵⁰

The U.S. influence in these congresses could be detected from early on; there was an emerging U.S. influence as the congresses themselves evolved. Soon after their formation U.S. non-scientific representatives had attended the second in the series (2LASC). More significantly, immediately after the national scope of the congresses had widened, U.S. representatives seem to have exercised undue influence at the organizational proceedings, thereby determining which issues would

be or would not be addressed. The Chilean organizing board of the 1PASC accepted almost all of the suggestions pertaining to division of sections and topics for discussion provided by U.S. representatives. These suggestions included issues of obvious U.S. economic interest: the pan American railroad, contagious diseases, immigration, bases of reciprocal commercial treaties, establishment of postal service, uniformity of international measures, uniformity of law with regard to bankruptcy, and so on. The U.S. had also provided a significant sum of money to its participants, \$35,000, which insured its influence. Many of the U.S. delegates to the scientific congresses had also been participants of the Pan American Congresses, which had been strictly diplomatic. These included Leo S Rowe, Paul Reinsch, William Shepherd, John Barrett, and others. Hence, their covert influence can be also detected prior to their overt posturing. Oddly, while the Chilean organizing committee published all of its meeting records, the U.S. organizing committee did not, thus shedding some suspicion on their activities.⁵¹



Figure 5: 2PASC medal⁵²

As shown by dependency theory, U.S. hegemony had its willing native elite accomplices. A surprisingly large number of presentations in the first two PASCs dealt with Latin American mineral and agricultural resources, in particular those needing development. In the process, they invited North American exploitation of their lands.⁵³ In addition, many of the delegates uncritically praised the U.S. role and its aims for pan-Americanism; any excuse to support it would do. For example, Alberto Santos-Dumont, a “world-renown inventor”, gave a lecture on, “How the aeroplane may affect closer alliance of the South American countries

with the United States.”⁵⁴ The lecture by the President of the Congress, Suarez Mujica, gave a great deal of support to the United States and their pan-Americanism. He felt Wilson’s speech had “...none of the imperialistic spirit in it; only the embodiment, the effectual embodiment, of the spirit of law, of independence, of liberty, and of reciprocal support.” Latin American nations, according to Suarez Mujica, were like weak birds which had been initially fearful of the Monroe Doctrine, but which would eventually come to see it as beneficial to them. The transfers of knowledge that occurred in these congresses proved U.S. goodwill. They erased all such misunderstandings; there was “no more propitious opportunity” and hence should be greatly taken advantage of.⁵⁵ By co-opting prominent Latin American leaders, the United States was able to insure a more favorable reception to the elements of its agenda.

Pan Americanism was pushed forth with a surprisingly diverse number of rhetorical devices at the 2PASC. One of these was the contrast of American democratic laws and customs to those of monarchical Europe, arguing that if Europe intervened, she would affect the self-identity and cultural integrity of the region. Similarly, if Europe invaded and North America fell without the support of its southern neighbor, they too would consequently fall, as they did not have the appropriate means of defense. If not by an emotional call, then an ontological argument would do—the two continents, despite their glaring cultural differences, were defined as brothers. Friendship was a highly pervasive theme. Lansing proposed that the keystone of the “Pan American arch” was fraternal helpfulness, while its “pillars” were faith and justice. Interestingly such aims could be achieved, according to William Jennings Bryan, not only by the exchange of students and professors, but also by the introduction of the 500 most important foreign words into each language. Despite the political differences of U.S. representatives, they all shared the same goals.⁵⁶

Yet, the crucial and underlying argument for pan-Americanism rested primarily on science. According to John Barrett, then editor of the Pan American Union’s journal and who would later become its head, “intellectual Pan Americanism was necessary to promote political Pan Americanism” President Wilson believed that if “America is to come into her own” then the “foundations of amity” had to be established beyond a doubt. The scientific congresses as the 2PASC had “enabled me to foresee how it will be accomplished.”⁵⁷

President Wilson explained its Hobbesian formula clearly. Science could only exist in the “atmosphere of mutual confidence and of peace and ordered political life among nations”; during times of war, the illuminating voice of science fell deadly silent. Hence, in order to have the peace necessary for progress, one

needed pan-Americanism. If both Americas reinforced each other against external threat, it would produce not only a military benefit, but also an economic one as well by its protection of the scientific enterprise. Science, however, was not only of general material benefit, but of a “spiritual” one as well. Mutual esteem and friendship, according to Wilson, cannot exist without a mutual set of goals. By providing these, science helped provide the basis of peace in the Americas as the pervasive amiability within the PASCs had shown; if science needed peace to develop, then science was at the same time the mechanism encouraging the harmony of nations.

Science affords an international language...because...there is a universal purpose, a universal plan of action, and it is a pleasing thought to those who have had something to do with scholarship that scholars have had a great deal to do with sowing the seeds of friendship between nation and nation. Truth recognizes no national boundaries. Truth permits no racial prejudice; and when men come to know each other and to recognize equal intellectual strength and equal intellectual sincerity and a common intellectual purpose, some of the best foundations of friendship are already laid.⁵⁸

The theme echoed throughout the congress’s halls.

Was President Wilson being opportunistic by making a frantic call for peace in the Americas while war raged in Europe? Were American delegates purposefully using the scientific congresses as a pretext to extend their nation’s economic hegemony to the south while at the same time weakening its native scientific base? In the end, is a “dependency theory” interpretation the correct one regarding the Pan American scientific congresses?

It is not.

The claims presented above have been gross distortions of the facts available and the general tone of the primary sources. Before a defense is presented with more information, we might make the following note of what is already known. The decline of science did not follow but rather preceded U.S. entry into the LASCs. This fact perhaps is enough to undermine arguments pertaining to U.S. scientific hegemony, especially so when it will be pointed out that the same could be said about most of the other critiques mentioned. The obvious should never be overlooked in a “court” of history.

Subject	1LASC	2LASC	3LASC	1PASC
Soc. Sciences	22 (19%)	85 (41%)	44 (36%)	394 (53%)
Science (basic)	50 (41%)	31 (15%)	24 (20%)	106 (14%)
(applied)	—	11 (5%)	7 (6%)	44 (6%)
Medicine	49 (40%)	69 (33%)	37 (31%)	120 (16%)
Technology	—	13 (6%)	9 (7%)	78 (11%)
Total	121 (100%)	209 (100%)	121 (100%)	742 (100%)

Table 2: Distribution of presentations by topic.⁵⁹

The rise of international scientific unions towards the second half of the nineteenth century was part of a more generalized phenomena non-specific to Latin America. Typical to its history, the Latin American scientific congresses broadly followed European patterns despite claims as to the differences between the two regions. All such scientific congresses were both the cause and effect of “progress” in that the development of modern transport systems such as railroads and steamships greatly lowered the costs of holding such congresses, while the congresses themselves stimulated further advancements to these technological systems. These systems had been focal points of the congresses, both in Europe and in Latin America.

On numerous occasions throughout the PASCs, the delegates were treated to train rides so that these might observe the latest advances in home nation, be they organizational or industrial.⁶⁰ Some delegates even complained that the LASCs had been too short, lasting only a week, and that for a more genuine congress, more than a month of deliberations were needed. Many who traveled to such congresses as these to journey further into the southern continent by either steamer or railroad—Bingham, Root, Gutierrez were a few of countless examples. The halls of the congresses were also manifestations of this emerging wonder. For example, the Teatro Solis at 2LASC was adorned by electric lights as had been Teatro S. Pedro de Alcantara for 3LASC—both created a wondrous spectacle to its viewers. For 2PASC, P.H. Thomas read a paper on electric power transmission and distribution, H. W. Fischer on underground cables, and Dr. A. E. Salazar, professor of “electrotechnics” presented a formula on electric transmission lines, showing how such equations could be “greatly simplified”. Illuminated by electric rather than gas lighting, they received numerous praises. The rapid use of this form of illumination is a bit amazing when compared to growth of electric lighting in the United States in the late nineteenth century. The Chicago Colombian Exposition of 1893 had made electric lighting the central focus of its display, and Edison’s Pearl Street Station had displayed the potential of electricity only in 1882.⁶¹

Paul Reinsch observed the sudden rise of scientific congresses in this period and noted their importance. Governments increasingly needed scientific advice because the nature of all projects tended to be more complex; similarly, some projects were so vast that they required the collaboration of various nations because no one single nation could afford to sponsor them. Also, and perhaps most importantly, the best knowledge had to be found, regardless of which nation it was found in; the congresses facilitated this quest in a highly effective manner. A few examples of the LASCs's European counterparts were as follow: International Geodetic Congresses in 1864 at Potsdam to determine the shape of the earth; the 1882 Paris congress on electric units for currents and standard measure of light; the 1884 congress in Washington D. C. to fix prime meridian at Greenwich; and one held at Bern to create a map of the world by geographers in 1901. Much of what we take for granted today, such as a universal time frame of reference, was the result of arduous and deliberate human action in these congresses. To have adjusted one's watch by an hour as one traveled from Chile to Argentina and back was something near miraculous to the respective delegates.⁶²

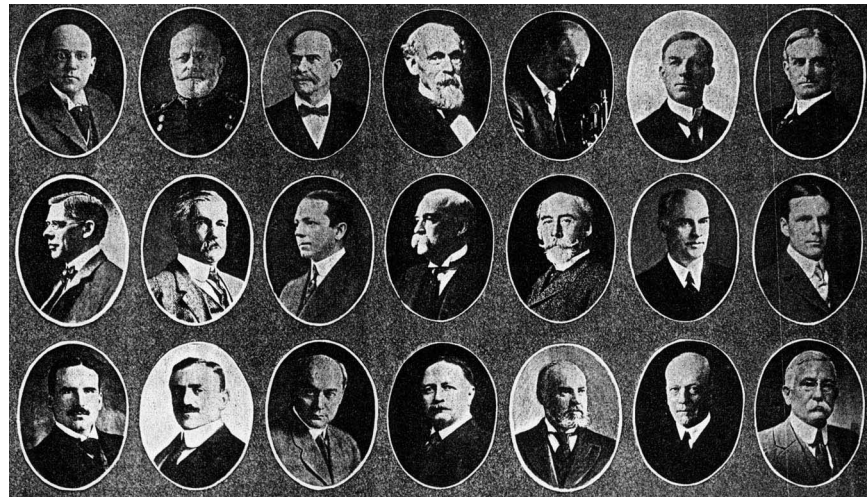


Figure 6: U.S. Delegates to 2PASC⁶³

W. W. Campbell in on top right corner,
 William Gorgas is in the very middle of the page,
 Leo Rowe is second from left, in the bottom row,
 William H Welch is fourth from left, bottom row.
 Figures are inappropriately labeled in the original document.

Maurice Crosland, who has studied scientific congresses held prior to the turn of the century, generalized Reinsch's observations by noting that one of their main purposes had been that of the "standardization of scientific language", or what more appropriately might be termed the "creation of an intellectual infrastructure". In other words, because the scientific notations and symbols employed within each European nation were different, an agreed upon means had to be found of appropriately unifying these into a coherent system be it for international projects or when foreign data was used. For example, meteorologists needed to establish comparable observations of what was going to be measured, common nomenclature had to be agreed upon for the classifying of specimens, and a common system of notation in chemistry had to be set, etc.⁶⁴ Surprisingly, the same had been true in astronomy at the turn of the century. Until coherent systems within each discipline could be established, the comparison of worldwide results pertaining to any topic would be costly and difficult, as perhaps shown recently by the crash of the Mars Climate Observer and the loss of \$125M over small numerical differences between metric and English units. Various presentations at the 1PASC pointed out these costs; all too often the lesson was learned too late as some observers then noted of hasty U.S. projects.⁶⁵

Indeed one of the most persistent attempts that could be seen throughout the congresses was that of standardizing the "language" of meteorology and chemistry. The attempts were not only symbolical, but organizational as well. In the 2LASC, for example, it was resolved to make observatories study different elements of weather such as atmospheric pressure, direction of wind, and the "estado de cielo en decimos." In chemistry, it was resolved to "unificacion de los metodos de analisis quimicos" Yet despite repeated attempts, the same resolutions had to be constantly introduced in each new congress because the congresses lacked any political power to implement these. For example, in 4LASC it was again resolved not only that national organizations and laboratories in chemistry be formed, but also that they adopt the current terms which had been agreed upon in Europe; it was also suggested that meteorological bases be established studying the same particular weather phenomena.⁶⁶ Although the native scientific congresses had very visible public governmental support, such as when the President hosting a banquet at his home⁶⁷, there were no formal and legal ties giving concrete power to the LASCs' and PASCs' countless resolutions. It was a problem international organizations have constantly faced, and which had been alluded to in the discussions of such things as the League of Nations.

Hence, Elihu Root's attempts to form an international law organization, analogous perhaps to the United Nations, should be seen in a more expanded con-

text. As technology itself advanced, international contacts themselves were significantly increasing, and an appropriate legal framework had to be found in which to fit the shrinking globe, not unlike the need of 1990's legislation to cover the new world of the Internet. One needed to force the law to catch up to existing technological realities so that abuses could not emerge when there was a lack of governmental oversight. A number of "liberal" aims were sought after in this respect. There were numerous lectures on the conservation of natural resources, and resolutions were passed pertaining to issues such as labor legislation, child rights protection, the creation of rural savings institutions for agrarian credit, and so on.⁶⁸ The aims were not to suppress weak nations but quite the contrary—to establish an appropriate forum in which conflicts and injustices could be amicably resolved. That most European congresses pertained only to European nations rather than colonies such as Africa suggests that nations without such bodies were likely more amenable to abuse than those without them. In light of the rapid European imperial expansion at the turn of the century, this was a rather noble cause. Yet, it was true of the internal politics of these nations as well. The lack of trust which Root felt characterized "south" nations is still true almost a century later. We should accept Root's words at face value.

We neither claim nor desire any rights or privileges, or powers that we do not freely concede to every American Republic. We wish to expand our prosperity...but our conception of the true way to accomplish this is not to pull down others and profit by their ruin, but to help all friends to a common prosperity and a common growth, that we may all become greater and stronger together.⁶⁹

Yet, in assessing North American efforts, it is perhaps even more suggestive that the goals sought after by Root had been predominant themes in the Latin American Scientific Congresses long before U.S. entry. The issue, for example, of creating an international legal institution had been suggested and debated as early as the 2LASC. Oddly, Dr. Manoel Avalro de Souza Sa Vianna stated that early European efforts at conflict resolution by arbitration (Italy, 1873) had been long preceded in Latin America by over three centuries! This is a rather curious statement when we consider the strong hesitance to place into foreign arbitration conflicts over territorial disputes in the region.⁷⁰ The issue of an international law organization, however, had been put forth and discussed, but not resolved in that scientific congress.

In a strongly worded speech at the opening session, Eduardo Acevedo, president of 3LASC, called forth the importance of and need for an international

body of law. The boundary disputes afflicting Latin America were worse than outright wars because although the latter ended at some point, the former tended to persist indefinitely—a truism when one considers that Chile-Argentina boundary conflicts have persisted throughout this century. Acevedo rightly pointed out that regional self-interest under these circumstances became highly inimical to the more general interest; as border localities tended to charge high tariffs, these were ultimately detrimental to the free exchange of goods between all nations. In addition, there were many legal disparities between the different national systems of law across Latin American nations. These and a great many other problems suggested that the formation of a great federation was essential for the general well being of the region. It was Bolivar's dream.⁷¹ Not unlike the resolutions in chemistry and meteorology, those dealing with international law prior to 2PASC were unfruitful.

Similarly, the idea of utilizing of science to create a pan-American fraternity of nations had also long preceded North American entry. In the very first congress held in Argentina, the intent of improving inter-American relations was purposefully shown in that foreign delegates were made officers of the congress. A Chilean, Dr. Paulino Alfonso, was elected president of that meeting; it was a symbolic gesture employed in all subsequent scientific congresses. Similarly, the Chilean delegates at the 1PASC suggested Peru host the following congress in Lima in an attempt to mend conflicts between the two nations over the valuable guano-rich Tacna Arica lands. Other overtures were also made, such as when both Argentinean and Chilean hymns were played alongside another. When a Peruvian delegate spoke, the predominantly Chilean audience loudly applauded him despite the fact that few could actually hear him. According to Dr. Emilio R. Conio, who had presented a paper at 1LASC, the members "pudieron darse cuenta entonces de que las disensiones entre pueblos no subsisten en el terreno científico!" Science was perceived as a peacemaker between nations, and effectively so in some cases.⁷²

That "scientific congresses" were used for diplomatic purposes should not surprise us, however; Reinsch pointed out that a number of European congresses, such as the Paris 1851 medical congress, had this dual function as well. Such diplomatic overtures at the LASCs and PASCs seem to have been very effective in some cases.⁷³

Yet the explicit idea that science was a tool that could be used to forge pan-American unity was a pervasive theme throughout the LASCs. In his response to an invitation to the second congress (2LASC), R. Errasuriz Ermeneta, of the Ministerio de Relaciones Publica de Chile, wrote in his response that, "Dados los

altos y beneficos propositos de esta Asamblea en que el amor a la ciencia unira con lazos de oro a las naciones que ella concurran...” Dr. Jose Arechavaleta, President of Executive Organizing Committee, made similar comments with regard to its purposes in the opening session of that congress. The Latin American scientific congresses had been created “para cambiar ideas, comunicarse el resultado de sus estudios, ponerse de acuerdo en cuestiones de interes general, estrechar lazos de amistad, estimular la accion comun en el progreso...” Although the congresses were imperfect because they could not be born perfectly out of Minerva’s head, they would gradually improve. Sr. Conselheiro Carlos Augusto de Caralho, the Vice President of the Comissão Directora of 3LASC, said that one of the purposes of the congresses was for inter-American peace; the LASCs would, “fixar na alma das Republicas...o verdadeiro lema de seus esforcos—justiça e paz.” The reasons he expressed for the soothing force of science were similar to those given by President Wilson.⁷⁴

One should also note that if there was any animosity towards the United States, it was not publicly expressed, whether in U.S. presence or not. Quite the opposite seems to have been the case. Most comments pertaining to the United States were highly favorable. It is curious to mention that a number of nations, such as Mexico and Brazil, referred to themselves as “United States of...(fill in blank).”⁷⁵ Frederich Ristenpart, director of the National Observatory of Chile, had very kind words towards the U.S. in his report of the 1910 LASC. A great many laboratories in Latin America owed their existence to U.S. efforts, and he thanked C. D. Perrine for being with them—even after having made so many important discoveries.⁷⁶ At a banquet for the same congress, Alejandro Alvarez said that Latin Americans should take heed of the U.S. Its wealth was due to modern science and technology. They “confirma, a todas luces, aquella apreciacion...[a la ciencia]...la America...debe aprovechar la inmensidad de los beneficios con que la naturaleza la ha dotado prodigamente...”⁷⁷ It is important to note that structural factors, such as the presence of science, are being attributed as the causes of wealth rather than relativistic ones, such as imperialism. In other words, it was assumed that a nation’s wealth was produced, not stolen. Some expressed that by attaining this powerful force, science, they would someday be to Europe what currently the United States was to Latin America.⁷⁸ During 3LASC, Sr. Augusto de Caralho had even confronted the issue directly—is South America against the United States. The answer was a definitive NO—“uma tal conjectura esta inteiramente excluida.” The U.S. actually provided a great deal of peace and comfort to the Americas where “as convulsões internas são motivo de inquietação....”⁷⁹

The changes made in the organization of the congresses were actually improvements on these. Summertime in North America is actually wintertime in the southern hemisphere. Similarly, North American delegates recognized that the educational summer session in Latin America was actually in December, and thus believed that by holding it then, to their own detriment, they would be furthering the good will between the two regions. More foreign scholars would be able to visit under this timeframe. It was also believed that requiring all U.S. delegates attending 1PASC to have some competency in Spanish would also contribute to improving their relations; all U.S. delegates delivered their presentations at 1PASC in that language.⁸⁰

It is important to note that the 2PASC, held by the U.S. in 1916 rather than 1912, was delayed because of the U.S. democratic political structure. As Root explained, a penny-pinching Congress constantly procrastinated in addressing the issue, much less funding it; he feared that if postponed further, it would seriously harm U.S.-LA relations. In fact, this was not the only time these delays had occurred. The U.S. delegates did not attend the first Pan American Congress (PAC, not PASC) for exactly the same reason despite favorable intentions. The 3LASC had also been moved from 1904 to 1905, but because of an excessively high number of congresses that year. By taking action, Root quickened the slow political process.⁸¹



Figure 7: Suarez Mujica in full regalia⁸²

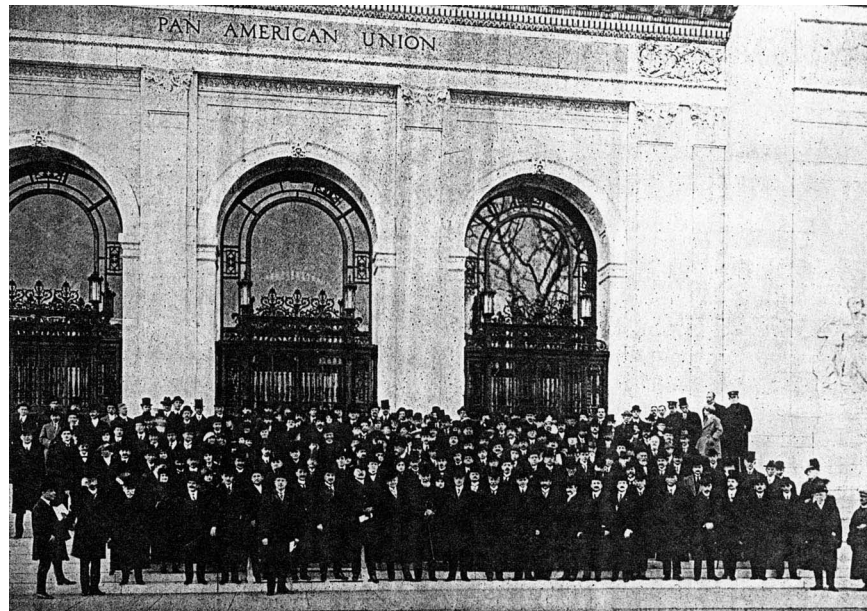
It could also be mentioned that Latin American supporters of the U.S. were no mere lackeys who were put in positions of power because of a certain Qualian naiveté. Suarez Mujica, who had been made official president of 2PASC, perhaps understood the meaning of the congresses better than most previous leaders. In a moving speech during the closing banquet at 1PASC/4LASC, he gave the LASCs most acute verbalization; it is perhaps the reason for his election to the presidency of the following congress.

Pleyades de jefes ilustres en los ejércitos de la investigación, legiones de cruzados de la ciencia surcan los mares y transmontan las cumbres para combinar, a la sombra de la confraternidad científica, los esfuerzos no menos heroicos que

tienden a asegurar la independencia—si es posible mas nobel y mas util,—la independencia del cerebro.

Suarez Mujica explained that Latin American political revolutions had to be followed by a consequent scientific revolution for genuine political sovereignty. The scientist was the new soldier who fought not only for freedom of conscience, but also that his contributions helped ensure these same ends. (“these”) It was a revolution that had already begun, and which someday would contribute ideas to Europe in contrast to its current flow. “A traves de un siglo de distancia, dos revoluciones agitan la America: la revolucion de la espada...y la revolucion de la idea.” If Latin American independence movements had been aided by the geographical movements of soldiers as when San Martin moved across the Andes to aid Bolivar, then scientists should also travel across the Americas to support one another. Certainly inter-American scientific cooperation had been poor in the past, but such congresses paved the way for the future. Suarez Mujica’s speech was perhaps the epitome of value transfer, where the scientist was made coequal to the soldier—a highly valued image in the Latin American psyche. Never before throughout the LASCs proceedings had the importance of science been so cogently framed in Latin American terms. Modern authors such as Noam Chomsky and Alan Sokal have also rejected critiques of science as an agent of cultural imperialism, pointing out that these injure rather than aid the less developed world.⁸³

The vast “passive-aggressive” anti-North American propaganda in so many current works within Latin American Studies is not a new phenomenon. Despite U.S. goodwill efforts, this propaganda was so pervasive by the turn of the century that a number of North American scholars in the 1920’s felt obliged to clarify its countless misstatements.⁸⁴ It is curious to note that supposedly “new” concepts such as “hegemony” at the leading edge of scholarship in our time had been used over 100 years previously in anti-U.S. attacks. Authors as Lockley then explained that, as today, they were usually highly vague and ill defined. A similar process occurred with the accusation of U.S. “imperialism”. It would be useful to go over some of their clarifications.

Figure 8: 2PASC Group Photo⁸⁵

It is difficult to accuse U.S. of the imperialistic charge, even when we consider its economic growth in the region. Empire is usually referred to mean the control of a large region by a small state in which political sovereignty at the periphery is greatly limited—as was the case with Imperial Rome. At a superficial level, the U.S. control over a few island territories begs the question of a parallel. While certainly it did hold control for some time, as in the Philippines or in Cuba under the Platt amendment, the general character was that of trying to form stable government and of giving liberty when sought after. As reflected by the long lines for immigration passports, Filipinos today ironically fight to regain with as much fervor that which was once so ardently rejected. Santo Domingo at one point offered to become annexed to U.S., but the offer was rejected. One also needed to distinguish colonization, or the populating of such regions, from imperialism. Certainly one cannot say that the North American population residing in insular territories constitutes the majority of the population, quite the contrary. Recent authors have also attacked the “neo-imperial” claim.⁸⁶

Yet, if the argument for U.S. economic imperialism towards Latin America is weak, that which could be made with regard to its scientific relations is weaker still—if it stands at all. While it might certainly be observed that, by the Second

Pan American Scientific Congress of 1915 the scientific element of the congress was minuscule in contrast to the First Latin American Scientific Congress of 1898, it can with as much certainty be stated that such trends preceded U.S. entry and had actually been gradually evolving with the congresses.

Similarly, the emphasis on Pan Americanism and efforts toward the stabilization of inter-American relations long antedated the 2PASC. Nonetheless, there was a very legitimate cause for Pan-American unification: some Germans claimed they wanted to take all Americans, northern and southern, to Africa and colonize the entire continent. The elder statesman Root rightly believed Germany was a predatory nation; "You cannot understand the Platt Amendment unless you know something about the character of Kaiser Wilhelm the Second."⁸⁷

Ironically, only when U.S. political influence was introduced and exerted were the goals long sought after by its southern neighbors achieved. The observation is worth repeating and amplifying. Although the ideas of a legal international body or pan-Americanism did not originate with the North Americans, in only one meeting the U.S. achieved what had been called for during the previous 200 years. This was partly due to the private wealth which dependency theorists so ardently criticize; it was used to financially support those bodies contributing so much to Latin American well being. These private philanthropies not only contributed to the cause of science at home, but they also proceeded to aid its development abroad.⁸⁸ One should not forget to mention that the costs of U.S. assistance had been primarily backed by North American tax dollars. U.S. involvement was catalytic to the region.

Even if one were to mistakenly use social events as a sort of litmus test for North American behavior, one's conclusions regarding U.S. hegemony would have to be questioned. Certainly things such as dinners held at the 2PASC were all under American influence, in contrast to the wide variety of different national hosts at Chile's 1PASC. However, we should note that their organization at the U.S. was much more decentralized, at individual homes, as opposed to the high centralization more typical of Latin American social events. Similarly, it should be noted that the percentage of U.S. attendees in the U.S. hosted PASC was much smaller in contrast to Chilean attendees at the Chilean hosted PASC; only about 450 of the 2,000 were native delegates in 1915.⁸⁹

Yet, if we have appropriately understood which causes were not at work, can we identify those that were? In other words, if the United States was not the culprit behind the decline of science in the congresses, then who or what was? As suggested by some studies of Latin American underdevelopment, it seems like the victim in this case was both the instigator and his accomplice.

2

“By the edge of the seashore”:



Modern U.S. Science in The First Pan American Scientific Congress

*“The importance of a problem should not be judged
by the number of pages devoted to it.”*

—Albert Einstein

The First Pan American Scientific Congress (IPASC) of 1908 was historically the most important. The decision to invite the United States gave it a new and unprecedented scope as the US had recently entered the world stage at scientific parity, and in some cases predominance, to that of Europe. This rapid growth had been somewhat surprising given its traditional practical-mercantile orientation.⁹⁰ If a secondary aim of previous congresses had been to eventually produce new ideas for Europe, here was an opportunity to stimulate this growth in association with colleagues who were more akin to equals than superiors were. Latin Americans, always attune to the latest advancements, were naturally turning to the most recent leading centers of science. North Americans at the turn of the century cherished a belief in progress because they witnessed these changes in their day-to-day life, and Southern Americans naturally wanted to partake in modernity's riches as well.

Yet, North Americans had much to gain as well from this first congress. Ever cautious in establishing amicable relations, domestically and internationally, they were being given a chance to show their goodwill to their southern brethren. The Spanish-American War a few years earlier had raised some questions of motivation, and Secretary of State Root, previously the Secretary of War who had directed U.S. activities during the war, was more than anxious for a return to the previous diplomatic status quo. The congress provided a highly effective forum in

which to address not one nation, but almost all sectors of the region. It was also unlikely to get another chance to participate in a forum that so encouraged honest and open debate. It was an opportunity that couldn't be missed.⁹¹

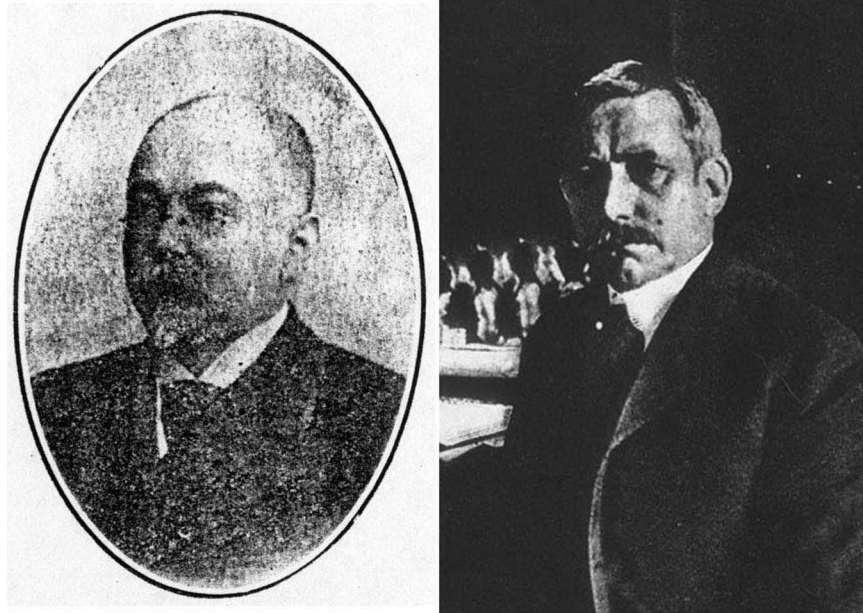


Figure 9: Valentin Letelier and Elihu Root⁹²

Partly due to these social dynamics, newer and revolutionary scientific ideas were brought to this 1908 PASC than in any of the other congresses that had either followed or preceded it. If one region had ample reason to take, the other had ample reason to give. These political dynamics perhaps explain why it was such a success in bringing world-class scientists and then considered innovative science to the event.

A great amount of work went into the preparation of the congress. Perhaps chosen because he was the rector of Chile's main University or because of his rather wide body of scholarly work in the humanities, Valentin Letelier quickly fell into his role by establishing the Congress's own organizational body within the university administration. Wanting to avoid the chaos of the poorly planned Uruguay congress of 1901, the group began to meet in May of 1907, about a year and a half prior to the actual December congress. All the things that needed to be done were done: subcommittees were formed, invitations were sent early to

respective governments, arrangements were made for lodging, travel, and entertainment, buildings were refurbished, and so forth. The committees of propaganda, which were really more akin to organizational subcommittees arranged by discipline, eventually grew to 417 members.⁹³

In their letters of invitation to the press and intellectuals throughout Chile, the organizing committee would typically inform that, “Creemos casi innecesario patentizar a U.S.. la importancia que tendra semejante reunion o insistir en las grandes ventajas de orden intelectual que, seguramente, derivaran de ella en el futuro.” About 127 foreign newspapers and journals ended up covering the event, while the members of the Chilean non-official delegation swamped the proceedings as previously mentioned. The Chilean government spent a significant amount of money on the occasion: 596,327 pesos; of which 367,944 pesos went to publication and distribution of works, 103,847 pesos for general costs as salaries, construction, medals, etc., and 97,536 pesos for social activities. So aware was it of the congress’ value that the organizing committee also decided to publish the minutes of its own meetings and a book about the current social and intellectual status of Chile—something no other host nation had previously done.⁹⁴ The last of the committee’s 50 meetings was held a few days prior to the beginning of the events.

In its outward form, the 1908 PASC resembled all other such congresses. The unofficial welcome was hosted on the 24th at the Club Santiago, a large park adorned with “las mejores flores chilenas.” About 1,200 attended the Club’s event, curiously referred to in Spanish by the English term “garden party”. The official inaugural session was held the following day at the Teatro Municipal, with seventeen speeches given by leading delegates and officials. While some genuinely recognized its importance, as Rafael Uribe of Columbia, others did not. Uribe stated that the congress was “para establecer el comercio de ideas...poniendo en relacion a los trabajadores aislados y coordinando y colectivando los esfuerzos parciales.” As had been done previously and would be imitated later, the president of the organizing committee passed the presidency of the congress onto another nation, in this case Brazil’s Don Carlos Ribeyro Lisboa. Three hundred girls from the Conservatorio Nacional de Musica, then sang the hymn of the fourth congress, “con un efecto grandioso.”⁹⁵

The upcoming week was followed by the actual proceedings where official delegates read and discussed their papers. Some of the “participants” who were unable to attend sent copies of their papers were also included in the published proceedings. Dispersed throughout the formal scientific gatherings were numerous social events as in most of the other scientific congresses—even more so than

in the later Protestant-hosted congress. A dance was held at the Argentinean legation on the 26th, while the Chileans held their own two days later with 2,000 participants. Visits were made to a number of facilities: sanitation, water treatment plants, sugar refineries, hospitals, agricultural schools, and so forth. Each section visited areas of respective importance—the physicists going to the seismology observatory while the zoologists went to the observatory of “virus carbuncloso”. President Don Pedro Montt at his Palacio de la Moneda hosted New Year’s Eve, attended by more than 3,000 guests. We are informed that festivities ended around 4:30 am. At the session de clausura, Suarez Mujica and others gave heart-warming speeches pertaining to the importance and value of science and the scientist. The emotive force of Suarez Mujica’s speech perhaps explains why he was selected to be president of the upcoming congress.

Internally, however, the 1PASC was obviously very different from what had preceded it or what would follow. Certainly, as in most LASCs and PASCs, scientific topics per se did not constitute the majority of the presentations in this congress. The pages of U.S. scientific material, for example, made up less than 1 % of the entire 1PASC’s published proceedings. Yet, their importance far outweighed their demographic representation. Their presentations contained the seeds of contemporary scientific revolutions.

North Americans would bring many goods as Root had requested, however, not only out of political self-interest, but simply because there was a lot of “new” science which had been recently created at home and abroad. While chronological divisions seldom coincide with intellectual ones, the dawn of the twentieth century certainly did: quantum theory, tropical medicine, genetics, and astrophysics to mention a few were some of the new sciences. Questions, which could never be asked, now were; models of physical reality were changing; and diseases that seemed to be “facts of life to be fatalistically accepted” were now alterable by the touch of man. Previous Latin American congresses, while certainly stimulating local interaction, had not generally raised the overall scientific level because it had not been in touch with the most advanced scientific thought of its era. By inviting U.S. scientific representatives, the 1908 PASC changed all that. If Latin Americans wanted to catch the scientific train prior to its rapid departure in the new century, this was the time to leap on before it was too late.

There were a total of 21 official and non-official U.S. delegates that presented a formal report to the U.S. Congress on the proceedings.⁹⁶ Curiously, official scientific delegates such as Colonel William C. Gorgas, Dr. Hiram Bingham of Yale, or Dr. W. B. Smith of Tulane University were not necessarily the only important members from a scientific point of view. Non-official delegates

included: Dr. Albert A. Michelson, of the University of Chicago, Dr. H. D. Curtis, of University of Michigan, and Dr. Thomas Barbour, of Harvard. Many of these names are most likely not immediately recognizable to the Latin American historian—except perhaps for Dr. Gorgas who assisted in the discovery of the cause of yellow fever in Cuba during the Spanish-American War and who was in charge of sanitation during the building of the Panama Canal. This need not mean they are any less important.⁹⁷

The age range of the delegates varied greatly—both Barbour and Bingham were young men while Michelson and Smith were nearing the end of their careers. While some had not yet established their scientific reputations, they were involved in the newest areas of their fields. Curtis for example had been working in the measurement of star radial velocities in Chile, a topic that bridged the older astrometry with the newer astrophysics. Their respective fields were as follows: Michelson-physics, Barbour-biology, Curtis-astronomy, Gorgas-tropical medicine, Smith-physics, and Bingham-archaeology/history. Bingham, although not formally a scientist *per se*, is included because of his discovery of Machu Picchu and consequent contributions to the understanding of Latin American history.

Before discussing their respective presentations, however, biographical and background material will be given so that the reader can more fully appreciate each individual's significance within the scientific enterprise—and hence their potential contribution to the diffusion of science in Latin America. The information here presented thereby does not constitute original research in the sense that it is based primarily on secondary material. However, the author feels it is still necessary to include it here so that those unacquainted with the history of science can develop a more grounded understanding of the congresses. This material will consequently take a substantial portion of the chapter; all too often, disciplines ignore each other's contributions.



Physics was undergoing a revolution at the turn of the century, and A. A. Michelson was an integral part of this change, albeit an unwanted one. The year prior to the 1908 PASC, Michelson had won the Nobel Prize. His invention of the interferometer led to highly accurate measurements of the speed of light, for which he was granted the prize. New absolute standards of measurement, i.e. the length of a meter, could now be carried out that were independent of an actual physical object serving as a standard, as the French had, carrying this golden mea-

sure in their Parisian vaults throughout the nineteenth century. Yet, his work with the interferometer would later be considered even more revolutionary for helping to dismantle previous physical theories based on the ether. Einstein, who forcefully challenged the ether's existence during his *annus mirabilis* of 1905, on occasion would attribute great weight to Michelson's experiments.⁹⁸ Michelson, however, was mainly an experimentalist who liked to refine and improve his experiments to perfection, a trait that seems to have negatively affected his personal relations and mental stability.

The well-known Michelson-Morely experiment carried out in 1888 had been preceded by the same experiment performed by Michelson in 1881 during his stay in Germany. If the Earth moved through the ether then there should be visible changes in the speed when measured across and against the "ether current"—yet no detectable changes were found. Some, as Fitzgerald and Lorentz, postulated an actual contraction of physical matter hence nullifying the difference. Michelson himself suggested that the ether was affected by mountains and believed that, until experiments were conducted in the upper atmosphere of a place like Mount Wilson, there could be no appreciable conclusion. Michelson, or most of the physics community, did not immediately question the existence of the ether, which initially had been postulated by Huygens as a medium for light to travel. If sound needed a medium of transport as air, then certainly light needed a similar medium; there was a reason for similarity in the two words—"aether" and "air". It took a long time before this theory gave way to negative results; it explained too much and was too embedded into the existing intellectual web. One of the presentations given by Michelson at the 1908 congress seems to have been a verbatim copy of his 1907 Nobel prize acceptance speech—in neither of them do we get an indication that the ether was under any sort of attack.⁹⁹

Despite these awards—U.S. astrophysicist W. W. Campbell had been nominated for the first Nobel Prize—to believe that the United States was a scientific giant in a manner analogous to an economic imperialist is to have an incorrect notion of its scientific development. Institutionalized research in physics per se in the U.S. was a relatively new phenomenon that had begun in the last quarter of the nineteenth century with the founding of universities such as Johns Hopkins, Chicago, and Clarke. Although physics was part of the American Association for the Advancement of Science, it did not form its own journal, *The Physical Review* until 1894 or a society, the American Physical Society, until 1899. Most physicists between 1870-1900 usually obtained their degrees in Europe; only 75 Ph.D. degrees had been awarded during this time. It was even difficult for the ones that

did exist to find suitable jobs—the industrial research lab or the vast funds of federal support, so typical of the post W.W.II period, had not yet emerged.¹⁰⁰

Certainly, the 1900-1920 period had been one of rapid growth, in contrast to the preceding decades. If there were 215 physicists in U.S. in 1900, by 1920 membership of the American Physical Society had grown to 1,300. There arose a number of new university programs and laboratories: Cornell 1906, Princeton 1909, Illinois 1909, and Yale 1913. Most were now choosing to get their doctorates in the US. Between 1900-1920, 20 U.S. institutions awarded 400 doctoral degrees in physics. The increase was even visible before this period. By 1900, the number of physicists had exceeded those in European giants; Germany, for example, had only 145 physicists in 1900.¹⁰¹

However, it should be pointed out that the productivity rate of U.S. scientists was still much lower than that of German or British physicists. For the 1.1 papers published by physicists on average per year in the U.S., Germany had 3.2 and England 2.2. Although increasing, this growth did not necessarily mean an increase in the quality. One should also point out that growth was exponential, thus grew at a much faster rate between 1910-1920, than between 1900-1910. For example by 1913, the APS only had 115 new members since 1900. The J. W. Gibbses, masters of theoretical physics, were very rare, in sharp contrast to the numbers found in Europe. The deaths of important physicists like Gibbs or Henry Rowland in 1901 and 1903 respectively were tremendous losses to the North American community.¹⁰²

The relative small size of the US physics community around 1908 meant that congresses as the PASC of 1908 were quite important to physicists for the exchange of the latest results and ideas. This was no more clearly revealed than at the St. Louis Congress of Arts and Science of 1904. It hosted 100 foreign physicists and 300 domestic ones; despite a much smaller congress than the IPASC, it contained a much higher concentration of leading theorists. European delegates who attended included Ludwig Boltzmann, Henri Poincaré, Paul Langevin, Wilhelm Ostwald, and Ernest Rutherford who had been in North America for some time, teaching at UCAL Berkeley and giving the Sillman Lectures at Yale (1907). The leading theories in physics were presented and discussed by the delegates. Poincaré had prophetically commented that physics was in a state of revolution.

According to A. Moyer, who has thoroughly studied the turn of the century physics community in the U.S., most American practitioners were aware of the changes such as Einstein's special theory of relativity or Planck's quantum, although few fully understood their significance. A 1906 article for *The Nation* perhaps aptly expressed the scientist's own feelings. "Today, science has with-

drawn into realms that are hardly [intelligible]...Physics has outgrown the old formulas.... In short, one may say not that the average cultivated man has given up science, but that science has deserted him." It is suggestive that Michelson did not attend the St. Louis Congress because of health and scheduling problems. He generally espoused the view that physics had been completed, that the only thing left for physicists to do was to add a few more decimal points to their calculations.¹⁰³ However, most who did go were members of a younger generation, as Robert Millikan, who did accept the theoretical changes much more readily than their older counterparts did, Michelson being one of these. Much of this information on the new physics had also been spread by means of the recent *Physical Review*. U.S. scientists tended to keep in touch by reading familiar English-language journals from Britain rather than the harder to understand German counterparts. The popular media also widely covered these advancements, including such Nobel prizes as the Curies in 1904, and Roentgen's 1897 x-ray work.¹⁰⁴ U.S. physicists were well acquainted with the latest advancements in their field.

The only other U. S. delegate who presented a lecture in physics at the 1908 PASC conference was William Benjamin Smith.¹⁰⁵ Born in 1850, Smith was an older man when he attended the 1PASC. Receiving a B.A. from Kentucky University, he later was nominated to receive the prize as best student during his graduate studies at Gottingen in 1876-9. There had been some controversy as to whether the award could be given to a foreigner, but he eventually did win the prize—incidentally the only North American ever to receive it. In his Doctor's dissertation, "Zur Molekular-Kinematik" ("On the Movement of Molecules"), he tried to extend thermodynamics to the motion of molecules in a discontinuous medium by applying the Maxwell-Boltzmann distribution laws. Smith also had studied Grassmann's works—complicated mathematics, which, according to him, had been far above his peer's abilities.¹⁰⁶ His ties to Gottingen are rather suggestive as it was about to become one of the leading centers of the new physics.¹⁰⁷

Curiously, in the years prior to the 1PASC, Smith had clearly shifted away from physics and towards theology. For example, in 1906, he wrote an article on calculus and another on the New Testament for the *Encyclopedia Americana*. He wrote *Der vorchristliche Jesus* in the same year questioning whether the biblical Jesus was a real person, an argument further developed in his *Ecce Deus* of 1911. Previous theological essays as a young scholar had dealt with the identification of biblical authors. In the winter of 1907-8, he also participated in the Congress of Modern Theologians in Amsterdam. The general character of his theological writing dealt mainly with biblical history.

Smith thus represents an enigma of sorts. Very much unlike Michelson, he did not fit the model of an increasing specialization in North American society but was more akin to its predecessor—the generalist.¹⁰⁸ Smith was so knowledgeable that he could have occupied all four chairs within a university, a reasonable claim. While more theoretically inclined than Michelson, Smith's ties to the physics community were much looser. Despite being trained at a leading center of physics in Europe, he was a Southerner who actually spent much of his intellectual effort attacking problems pertaining to theological issues. It was for this latter work for which he is distinguished as a scholar, not for his work in physics.¹⁰⁹ Smith likely shared the isolation felt by all Latin American scientists; unable to talk to his peers, he shifted into other areas of more pertinent interest. As Einstein once said, "What is not socially appreciated does not develop even in gifted individuals."¹¹⁰ Ironically, however, while Michelson did not address the new theories of physics in his lectures, his colleague did. Smith, who was multilingual, was also one of the few to actually deliver his presentation in Spanish.¹¹¹ Teddy Roosevelt had personally extended an invitation to Smith, and with good reason, as we shall see.

Another participant was Dr. William C. Gorgas. When invited at the age of 54, Gorgas had been assisting in the construction of the Panama Canal—a project initiated by the French in the 1880's under Ferdinand de Lesseps, but which had failed in part because of the high death rates from tropical diseases. Gorgas, who had previously served as sanitation officer to Cuba in 1898 and as a result aided in the discovery of the nature and cure for yellow fever, knew how to control tropical diseases by the year of his appointment to Panama in 1904. The main line of attack was relatively simple: get rid of mosquitoes. However, achieving this goal was much more difficult than it seemed.

According to McCullough, Gorgas had confronted numerous problems when he began, in part because the Director John Wallace had stifled Gorgas's work by limiting his supplies in order to keep costs down—financial difficulties had also overwhelmed the French because of poor engineering design and Wallace was trying to avoid these. However, he had misapplied the lesson and suffered greatly as a result, losing his wife and children to the black vomit. With the appointment of John Stevens as new director in 1905, there was a quick turn around. If Wallace had denied Gorgas's request for 2 tons of newspapers to fumigate rooms claiming that it was too much material for reading rooms, Stevens overturned Gorgas's \$50,000 spending cap, in one case giving him \$90,000 for screens alone. With these new resources, Gorgas was able to keep tropical diseases at the site under control until the project was finished in 1913—not bad for a man who

had once vehemently opposed the idea. "I can recollect...having spent a good many hours trying to show Dr. Finlay the absurdity of his mosquito theory, but the doctor was a veteran who had already had sixteen years' experience in meeting arguments of other men like myself who knew that his theory was an absurdity, and he would not be convinced."¹¹²

Yet Gorgas's problems were also due to expected lags arising during paradigm changes. As Jerome Ravetz has written, a new science is obviously not fully developed to address all problems, and thus initially requires a degree of faith for its practice. Tropical medicine, or the discovery that vectors such as insects transmitted certain diseases, was a relatively new science. Even after he had finished fumigating, the problem did not immediately go away, thereby probably raising some doubt in Wallace's mind as to the validity of Gorgas's approach. Even when he knew what the basic vector of transmission was, i.e. mosquitoes, the problem had not been resolved. Gorgas still had to identify all possible breeding grounds as well as flight paths in order to eventually meet the adequate health standards he claimed his methods could obtain. Not only was it an issue of funds, but also it was an intellectual process that took time to mature. He is not the only scientist who suffered because of this cultural lag. When the "father" of tropical medicine, Patrick Manson, returned to England in 1889, he was ridiculed for his ideas and called by the pejorative term "mosquito Manson." Charles Stiles had also been calling for the eradication of hookworm since the 1890's in the U.S. South, but it was not until 1908 that the nematode was finally recognized as a source of the disease in the region. Men are not gods born with innate ideas but have to slowly develop these in a step-by-step approach.¹¹³ The origins of tropical medicine, and attributing recognition to Latin American scientists like Carlos Finlay, are somewhat complicated for these reasons. Discoveries also create new standards of evaluation making their initial intellectual climate much harder to understand and assess. Men like Finlay are caught between multiple conflicting paradigm-cultural schemes.¹¹⁴

Similarly, Gorgas was affected by the institutionalization of medicine in the United States. Throughout this period, scientifically trained physicians were gaining ground in effectively controlling the medical market by preventing a "quack's" legal practice. Paul Star argues that their success was not only due to the rise of bacteriology in the 1880's—a science which could visibly cure and be extended to many diseases—but rather was affected more by legal and institutional maneuvers. Yet until control of educational institutions and licensing was gained, a great deal of ineffective medicine remained. Abraham Flexner's *Bulletin Number Four* of 1910 was a devastating critique of the existing educational medi-

cal system; its criticisms had been preceded by the American Medical Association's own study of 1906. The conclusion of both was that there were just too many bad schools. In 1890, for example, sectarians had 106 medical schools; homeopaths had 16, and eclectics 9—all sources of ineffective and shoddy medicine. After the report, as the number of physicians and schools declined, the quality of common medicine greatly increased. North American egalitarianism did not bode well with the rigor of scientific development.¹¹⁵

Of all the U.S. delegates in the 1908 PASC that were scientists per se, Heber D. Curtis had been the most professionally acquainted with Latin America. Joining the Lick Observatory in 1902 on a mid-career change, Curtis was sent by its director W. W. Campbell to Chile between 1906 and 1910 as part of the D. O. Mills expedition—a program studying radial velocities of stars in the southern hemisphere. Curtis actually presented at the 1PASC a summary of his Chilean work, including a list of the spectroscopic binaries he had also identified.¹¹⁶

Curtis was one of the few practitioners of astrophysics in the United States—a new trend in astronomy studying the constitution of stellar entities as opposed to their movement. The study of radial velocities is not a visual study of movement across the line of sight but rather of movement within it—in other words, of an object's movement to or away from the observer. Conducting a systematic survey of the sky in such a manner provides information pertaining to the structure of the galaxy, believed to be the most predominant body in the universe. Visual observations obviously could not do the trick for these studies. Rather astronomers turned to the only possible tool: the spectroscope—a “prism” that divides a light source into its constituent frequencies. Each light source like a star or a nebula provide a characteristic “fingerprint” which can then be studied to identify things such as chemical components and radial velocities, the latter which is identified by recognizable Doppler shifts in its spectrum. The work is not as easy as it might seem. Although the prism was older than Newton himself, the development of spectroscopy had been hindered by the presence of salts in most chemical samples. The notorious D line in all chemical samples had prevented generalizations about spectra until almost the last quarter of the nineteenth century. New methods in spectroscopy as those engendered by Bunsen and Kirchhoff and new tools as the photographic plate provided new means for grasping the truths of nature—in this case, literally the universe. Although radial velocity studies were no different from traditional analyses of stellar movement, they were conducted with the latest tools of astrophysics.¹¹⁷

What is perhaps perplexing is how “primitive” the model of the universe was at the turn of the century—a somewhat medieval model in which the galaxy

stood at its center surrounded by a lot of empty space. Perhaps the pervasiveness of this idea, the centrality of man and his world, should not be surprising: changes in astronomical paradigms are very slow, as Galileo's fight with the Church had shown. Astronomers had remained fixed on "Newtonian" astrometry for centuries, and the technology really had not advanced that much until the end of the nineteenth century. Only recently to the 1PASC were reflectors being used to increase the capacity of telescopes.¹¹⁸ Yet, even a leading astrophysicist such as George Ellery Hale did not challenge this model.

Hale in 1908 claimed that the Laplacian conception of the solar system could not be questioned because the spectra of distant spiral nebulae was continuous, thereby suggesting that these were composed of simple elements in contrast to our more complex sun whose spectra contained absorption lines. William Huggins, an astrophysicist who would later publicly reverse his position in 1899, had given proof of Hale's claim in 1864. Perhaps too much evidence weighed against the idea that nebulae, faint clouds in the lens of small observatories, could possibly be distant galaxies. Otto Struve had detected changes in their brightness in mid century, and in 1885, a nova (supernova) in the Andromeda Nebula grew to 1/10 its total size—both of which were considered impossible if the nebula had been a galaxy. Man and his world would remain centrally placed in God's universe; there were simply too many unknowns. As the physicists of this time, astronomers lay between a very old and a radically new concept of the universe. U.S. astrophysicists like Curtis, however, would help change this picture.¹¹⁹

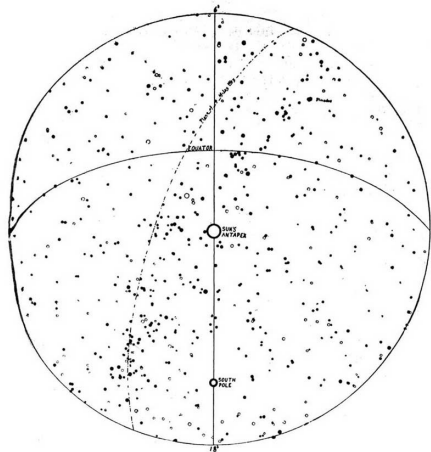


Figure 10: Curtis's maps of radial velocities in the Southern Hemisphere¹²⁰

Curtis's main body of work in Chile was conducted at the San Cristobal Observatory near Santiago, where a major riot in 1903 had occurred. During his stay Curtis also explored the region around the city for potential observatory sites where the world's most advanced optical observatories now rest: La Silla. There is a peak now called "Cerrito Curtis". Curtis's work was so advanced that the director of the Chilean Observatory, "Federico" Ristenpart, had even offered him a position as head of an astrophysics section in 1909—an offer that Curtis ultimately turned down. This was perhaps to be expected.¹²¹

Born in 1872, Curtis stood at the mid-age bracket amongst his colleagues. Not having quite yet reached the pinnacle of his career by the IPASC, Curtis during this time does not seem to have been a fully independent researcher but rather was mainly following Campbell's research agenda. This was usual given the increasing reliance in astronomy on "Big" telescopes. The changing nature of astrophysics and its more sophisticated equipment meant the eventual creation of a necessary corporate atmosphere requiring the autocratic personality the likes of Campbell to lead these new institutions. The expedition to Chile had been named after the local California businessman who had not only philanthropically sponsored the Lick with \$700,000 across a long span of association, but had been convinced by Campbell to provide funds, \$24,000, for his new research project. It is curious to point out that Campbell, as a result of his courting the moneyed elite so typical in this period, was given funds by Phoebe A. Hearst (widow of George Randolph Hearst) to purchase the Lick Observatory's first automobile in 1908—making the dreadful journey up the hill that much easier.¹²² The D. O. Mills expedition would eventually conclude with the publication in 1928 of 10,310 spectrograms. By then, Curtis had certainly developed the professional maturity and renown he previously lacked.¹²³

By the mid 1910's, however, Curtis had become the main spokesman for the "island theory" of the universe. Bringing forth the most cogent arguments in support of the theory, and the most dreadful attacks on rival theories, he represented what Shapely referred to as the "Lick state of mind". Shapely, of course, used it as a pejorative for what he believed to be an excessive conservatism by that group. The now titled "The Great Debate" in astronomy took place between Curtis and Shapely publicly in the halls of the National Academy of Sciences in 1919 and privately in the pages of the *Bulletin of the National Research Council* in 1921. Shapely actually did not challenge Curtis greatly in the public forum, possibly because a potential loss might have led to a retraction of a position at the Harvard Observatory to which he was applying. Both, however, certainly were extending the boundaries of astronomical knowledge. Shapely, using new statistical meth-

ods and Cepheid variables, had greatly expanded the size of our galaxy from the previous 20,000 light years to 300,000, thus giving it a significant portion of the universe and accounting for the nebulae seen in its fringes. Ironically Curtis, who had attacked the use of Cepheid variables as an astronomical measuring rod as late as 1921, finally accepted it when it was used by Edward Hubble in his support of the island universes theory—a much larger and more complex scheme than the one supported by Shapley.

As might be observed, the leading edge of astronomical science by the turn of the century rested not in Europe with its mid-city observatories but rather in the United States with its mountain Olympuses. If it was at parity, or slightly below parity in other sciences, by 1908 the U.S. had outrun Europe in its race for the stars—a lead that would continue to grow during the first half of the century. The largest telescope in the world was the 60 inch reflecting at Mount Wilson, built in 1908 whose cost, not including dome and mountings, had been estimated at \$66,700. There had been a sort of “Cold War” between different U.S. institutions in the last quarter century to try to build the largest refracting telescopes—18.5 inches (1862), 25 inches (1871), 26 inches (1873), and the 40-inch Yerkes Observatory built in 1897. However, these telescopes, as was the case with the Yerkes, had a much lower “upper limit” than that of reflecting telescopes. With their thick lenses, they tended to sag under their own weight. Advancements such as silver coating, George Ritchey’s mountings, and the use of glass instead of metal as a base greatly improved the efficacy of reflectors, which by nature were cheaper to build than refractors. Yet, despite their lower cost, most large reflectors built in the first quarter century were built with funds from the philanthropical foundations of the economic upper strata. Hale, who would dedicate his entire life to astrophysics by building its organizational and institutional foundations, came from a wealthy industrial Chicago family.¹²⁴ Osterbrook calculates that the amount paid by Hale’s family for his private Kenwood observatory, \$25,000, would have cost \$400,000 in 1992. George W. Ritchey, who had helped design the Wilson Observatory, had been previously asked to build a 40-inch telescope by Aristarchos Beloposky, director of Pulkovo Observatory in Russia. When Ritchey estimated the price tag at \$40,000, Beloposky withdrew the request; Ritchey’s further lowering to \$30,000 still did not change Beloposky’s mind. Reflecting telescopes were cheap, but obviously not cheap enough.¹²⁵ It is unrealistic to believe unindustrialized Latin American nations could have participated in this one scientific race.

It might seem surprising to us that a young man who had yet to finish his Ph.D. should be asked to participate in an international congress of such import.

However, Thomas Barbour, born in 1884, showed many traits that would make him an excellent scientific diplomat. As early as 1907, he had already participated in the Seventh International Zoological Congress in Boston. A tall and gregarious man of a well-to-do family, Barbour had been forced to live in Florida during the first year of the Spanish-American War after a serious bout of typhoid. As a result, he had become fluent in Spanish—a deficiency of which so strongly annoyed multilingual Latin Americans. Barbour also had a relatively strong research background. During his honeymoon in 1906, Barbour traveled across the Malay Archipelago influenced by a reading of Alfred Russell Wallace, Darwin's intellectual nemesis of sorts. Barbour gathered so much data during his trip, that by 1912 he had 47 scientific papers to his name; by the 1PASC, he had already published 19 articles. His encounter in Chile would introduce him to a life-long association with Latin America's flora and fauna. Although other delegates (Reinsch for example) were not asked to attend later meetings, Barbour would again travel to Mexico City in 1910 to represent the Association of American Universities—the same year in which he finished his Ph.D. During W.W.I, he would also serve in Cuba as a U.S. diplomat, and would maintain life-long relations with many colleagues of the island. In hindsight, Barbour was a highly favorable candidate for the occasion.¹²⁶

However, unlike the much older Michelson who had a well-established reputation behind him, Barbour perhaps did not appear to have that much to contribute to the congress as requested by Elihu Root. His youth was a double-edged sword. Barbour's few formal credentials by the time of the 1PASC perhaps explain why, despite the fact that he gave a highly suggestive presentation at the congress, it was not published in its proceedings.¹²⁷ Unlike Curtis who brought with him the new astrophysics, the young Barbour generally represented a much older methodology in North American biology that had been giving way to a more rigorous experimentalist one, a trend which itself imitated recent advances in European biology. Although young, Barbour was not new.¹²⁸

The intellectual, methodological, and organizational changes North American biology underwent between the 1880's and 1910 were both radical and highly complex. This has to do not only with the complexity of the ideas, but also with the institutional decentralization that characterized the community, very much unlike chemistry which had a coherent national organization at this time. The shift towards Jacques Loeb's *Entwicklungsmechanik*, however, was visibly clear during the first decade of the century. For example in the journal, *The American Naturalist*, articles pertaining to natural history rapidly declined from 89% to 47%, while experimentalist ones increased from 11 to 53% between 1900 and

1912. The conflict between the two main camps arose not only out of epistemological and ethical differences, but was also due to certain weariness with grand philosophical systems as Charles Darwin's.

Ironically, although Darwin's particular ideas about evolution had generally been rejected by the North American community in 1900, a great deal of work was being done which would unknowingly provide the most powerful support for Darwinism. This work would eventually culminate in the "Grand Synthesis," completed a few years prior to World War II. The Darwinian scheme in 1900 was problematic for many reasons, primarily because it generally viewed natural selection as the only means of speciation and because it had no mechanism to account for the creation of new traits.¹²⁹ Not only had the Neo-Lamarckians come to the fore in their spiritual support of Man's ability to control his world, i.e. his Will, but academic biologists had also turned away from grand schemes of heredity to more specific and concrete problems such as those in embryology. A contemporary of Darwin's, Gregor Mendel, held the key to evolution. It is curious to mention that not only had Darwin dismissed Mendel's article when personally sent to him by Mendel, but also that Darwinists at the turn of the century would also dismiss the newly discovered Mendelian genetics, perceiving it as antithetical to their own framework. T. H. Morgan, who would redefine with his students Mendel's work into the field now known as genetics in 1915, had at first dismissed genes as hypothetical constructs of the imagination—a theme so pervasive of the era. Mendel's ideas ironically entered North American biology not where one would expect, via academia, but rather by the federally supported agricultural research stations flourishing at this time. The ever practical North American was interested in Mendelian tables not for what it could explain about the nature of life, but rather for how it could help him grow better crops. Although Darwinism was alive, it was nowhere to be found.¹³⁰

Barbour did not seem to quite fit into this new world of American biology because he was neither an experimental embryologist nor a statistical geneticist. Despite his young age and these new avenues of research, Barbour was a biologist who more resembled the likes of Darwin and other biologists a half century before—that of the wealthy gentleman naturalist. It was a distinction he was rather proud of, and which he accentuated in his *A Naturalist in Cuba* (1945) or his autobiography, *A Naturalist at Large* (1943), avid popularizations of the naturalist's lifestyle and approach.¹³¹ Fitting into this image, Barbour was never paid during his life-long tenure at Harvard's Museum of Comparative Zoology, despite biology's professionalization in the period. He actually provided ample sums to the MCZ throughout his tenure, something that may have influenced his

appointment as its director in 1927. His family's wealth would also support the Barro Colorado Laboratory in Panama—an island formed when the region was flooded to create the canal. Yet, despite his nineteenth century manner, Barbour was ahead of his era.¹³²

Barbour pursued lines of research that more than a half-century later would be resolved and incorporated into the Darwinian paradigm by such biologists as Theodosius Dobzhansky, Steven Jay Gould, and E. O. Wilson. Barbour was an island biogeographer.¹³³ In 1915, Barbour entered a public argument with W. D. Matthews over the existence of a “Wallacian line” between Jamaica and Cuba. Matthews was a Darwinian who abided by a Lyellian uniformitarianism—the Earth did not undergo radical changes—and hence believed that changes in the mammalian fossil dispersion record of the southern U.S. could be explained by occasional storms. Barbour strongly disagreed. Like his intellectual mentor Wallace, Barbour showed that the ocean was so deep between these two islands, that it had consequently created a geological barrier between them. The geological landscape had been significantly different from what it had become, thus creating an isolated environment suitable for what would later be known as punctuated equilibrium.¹³⁴ Barbour made a few simple demonstrations to show that species common to the smaller Antilles could not have survived even a day in the ocean, much less a long ocean voyage. The particular dispute between the Matthews and Barbour, however, would not be resolved until the later emergence of plate tectonics. As had occurred previously, in order for biology to progress, geology would have to make advancements as well—not unlike the stagnation of astronomy due to paradigm stability in physics. It is fair to say that, like many of his PASC colleagues, public debate marked Barbour's scientific maturity.¹³⁵

Born in 1875, Hiram Bingham was as Barbour a young man yet to make his mark in the scholarly world. Both were also very tall men who shared a love of exploration; Hiram was 6'4" while Barbour was 6'5". To write his dissertation on Scottish business influence, he traveled throughout Europe and the Caribbean, including Puerto Rico, Crab Island (Vieques), and Venezuela, in search of records and evidence. At one point, he even sought to retrace Bolivar's steps across the Andes. The wealth Barbour had inherited, Bingham had gained by charm. Married in 1900 to an heiress of the Tiffany family fortune, Bingham was able to indulge in his interests like no other Latin American historian of his time. Before obtaining his first job, Alfreda Mitchell's parents had given the young couple a 26-room mansion for their first home. The similarities between the two men do not end there. The IPASC would eventually introduce Bingham to the

region that would mark his reputation as a scholar; in 1911, he would discover Machu Picchu.

Constantly torn between scholarship and adventure, Bingham was a turn-of-the-century Indiana Jones. Woodrow Wilson, then President of Princeton, had personally given Bingham a position as part of a special pilot project in 1905, from which Bingham withdrew that same academic year because of its supposed time-consuming activities. He had to read too much. Bingham, like Barbour, would then obtain a non-paid professorship at Yale, his Alma mater, where he was able to freely indulge in travel without the necessity of teaching as a professor. Ironically, however, Bingham really did not have much expertise in either archaeology or Meso-American studies prior to his discovery. The "discovery" was somewhat of a fortunate encounter with a site well known by locals in the region whom had led Bingham to it.¹³⁶

Yet Bingham truly was a pioneer in that he was one of the few Latin American historians in the United States at the time—a field the North American academic world would recognize in the 1PASC needed substantial more development. On his many trips to Latin America, Bingham had also served as a book collector for the libraries of Yale and Princeton. If the two continents were to establish amicable and long lasting relations, they simply needed to get to know each other better. Bingham not only helped the United States learn about its southern neighbor, but also helped this southern neighbor learn more about itself.¹³⁷

The U.S. delegates here reviewed represented leading sectors in the intellectual economy of science. Michelson had greatly advanced the study of light, Curtis was better understanding the overall structure of the universe, Gorgas was one of the leading practitioners of the new tropical medicine, and Barbour pursued issues which were so far ahead of his day, that they would not be resolved for decades. It should then not be surprising that their presentations had the potential to thoroughly reorient the scientific enterprise of almost all of Latin America. Instead of going to the leading centers of science, with the 1PASC Latin Americans had very ingeniously brought these centers to native soil. Let us briefly look more specifically at what U.S. delegates exposed about modern science.

It is unclear whether Dr. M. J. Rosenau, Simon Flexner, and Dr. H. R. Carter, actually participated in the 1PASC's proceedings. They were not listed as delegates to the congress, and unlike the 2PASC's more lengthy report of 1915 in *Bulletin of the Pan American Union*, the report of 1908 did not give a complete list of all participants. It is reported that many participants, U.S. and non-U.S., actually sent papers which were presented by their respective delegates. One

might also note that the number of attendees at social gatherings, as well as the official roster, far exceeded the number of recognized delegates. Whatever the case may be, in contrast to Thomas Barbour, their respective presentations were published in the proceedings—thus making their ideas widely accessible to the Latin American scientific community. Along with Dr. Gorgas's paper, they represented the latest of North American medical research. Although three other Pan American Medical Congresses had been held up to 1901, they preceded these advancements carried out by U.S. investigators.¹³⁸

In his "Últimos adelantos en el estudio de la fiebre tifoidea," Dr. Rosenau described what had been discovered in the last decade or so about typhoid. Walter Reed's work of 1898, Robert Koch's of 1902, Conradi and Drigalski's method of identifying bacillus in excrement, and the infamous case of "Typhoid Mary", a cook who contaminated all of her culinary customers, were all included in his report. More importantly, Rosenau described the most common vectors of transmission and consequently the most effective means of its control. He reported that the bacillus mainly spread by non-treated water (40%), but also through milk (25%) and human contact, mainly in children. Common household flies also spread the disease as they flew from excrement to food, thus spreading the bacillus. The doctor had been in charge of a 1906 Commission to study typhoid in Washington DC. Simon Flexner similarly reported on the latest discoveries, in this case of a new serum developed by the Rockefeller Institute for Medical Research against the deadly meningitis. Deaths in adults who were caught in the earliest stages of the disease were reduced to 14.9% of all cases. The implications for the conquest of the disease were relatively clear.¹³⁹

Perhaps to be expected, Dr. Gorgas reported on his work with yellow fever in Cuba and Panama; Dr. Carter, who was the Director of Hospitals at the latter site, also discussed Gorgas's work. Curiously, they provide a very different interpretation of the doctor-patient relation than that given by some historians.¹⁴⁰ The main issue Gorgas addressed was not the vector cycle but actually the legal and organizational frameworks doctors would need to cure people. This was to be expected given the medical and legal difficulties U.S. practitioners in tropical medicine had faced, as previously discussed.¹⁴¹ Gorgas himself specifically mentions some of these. Although the city of Havana had the disease in endemic fashion for about one and a half centuries, its population proved highly uncooperative to its treatment. Gorgas felt that Latin American doctors who wanted to get rid of the disease would have to similarly fine citizens who did not take measures in eradicating the *stegomyia* larvae, and give the physician some amount of legal superiority to enforce these. He also described what he felt was

the most effective organizational structure, municipalities of 600 houses, and expected costs of such measures, about \$1,900 per month.

Dr. Carter, in turn, explained the principles of such an approach. Attacking the *stegomyia* mosquito outright, which lacked a judicious scientific approach, had always been considered a secondary means to treating a population. The main aim had always been to place infected persons in "quarantine", yet not from other individuals but from the insect vector. It had been found that although a patient could only contaminate the insect during a period of four days, the mosquito itself could be "contagious" for a much longer period of a month and a half. Careful scientific analysis thus provided valuable information about the Aquiles' heel of the disease—prevent the mosquito from becoming infected in the first place. In small communities where the disease was not endemic, Carter informs us that the vector-patient quarantine could be easily accomplished. However, it was practically impossible to implement the procedure in large urban areas because of patient uncooperativeness. The most pernicious obstacle to treatment of yellow fever had not been the natural world, but rather the human one. Partly for this reason, the last and only means available to the physician had become an all-out war against the mosquito; this would clearly diminish doctor-patient conflicts while being much more efficient and effective. The same had been true of malaria, a disease also spread in the same manner.¹⁴²

A. A. Michelson's five pages, in contrast to the common 50 page-long presentations of the Legal subsection of the IPASC, were not a presentation in the latest theoretical physics. Planck, Einstein, Zeeman, Thomson, and the names of other leading scientists never enter its paragraphs. His presentation in fact was thoroughly framed within a mechanistic conception that had become increasingly obsolete by this time—the world as the result of colliding particles. Not even Maxwell, who had initiated the revolution against this view, would be alluded to. The only scientist he ever mentioned had died more than two centuries ago: Sir Isaac Newton. Similarly, typical of the non-theoretical inclination of North American physicist, Michelson spoke only of instruments and techniques for carving notches and making screws. Theories were but passing themes of relatively minor importance; Michelson would not feed his audience with the latest ideas in the field. Instead, he would do something more important. He would provide them with the tools that allowed these advances to take place.¹⁴³

In his "Recientes progresos en la Espectroscopia" Michelson gave a thorough presentation on the construction of spectroscopes and interferometers.¹⁴⁴ More importantly, however, he provided information as to how best assess the quality of these scientific instruments. If the quality of a telescope could be judged by its

ability to detect double stars, then the quality of a spectroscope could be judged by the distance formed within its spectra—the broader the distance between the line, the greater its precision. The most advanced spectroscopes, he informs his Latin American colleagues, were built and designed by Henry Rowland, which had been used by the North American community for the past twenty years. Rowland's diffraction gratings were so accurate, that its 100,000 lines notched across a distance of only 50 millimeters could theoretically divide the double D line 300 times. One could even detect the effects on magnetism on spectra—perhaps alluding to the Zeeman effect (1896) and the internal complexity of the atom. Some of the most important elements in the construction of spectroscopes were the stability of the screw and the temperature of the materials, of which slight changes would render the final product relatively useless. Ever the perfectionist, he showed his audience how to avoid 100 years of instrumental defects. Michelson certainly was not there to fool anybody.¹⁴⁵

Despite the importance of the papers previously reviewed, there was something uniquely magical about William Benjamin Smith's, "Nuevas teorías de los fenómenos físicos".¹⁴⁶ In it, Smith was uncovering the newly charted territory created by J.J. Thomson's electron, making an open invitation into the field. As the title perhaps suggests, Smith believed he was presenting the latest advancements, not only in "the New Science" (physics), but rather in all of science. As he made clear to his audience, "no hay un tema de significado puramente científico que sea mas importante, o que se encuentre mas central en la escena del interés, o que sea mas digno de la atención de los sabios reunidos de dos continentes."¹⁴⁷ The electron and all related work, as is now well known, would have profound effects on all the other sciences—a point which Smith explicitly emphasized throughout his lecture but whose validity he was not entirely aware of. In his speech, Smith was delivering a new science to a new audience for ready consumption. The scientific subject was relatively unexplored and thus full of possibilities for any scientist entering the field. Three years later, Ernest Rutherford would discover that the atom was mainly empty space, and it would not be until 1932 when the search for the main ingredients of the atom would be "completed"—a race which theoretically was still open to Latin Americans.

In 1908, atomic physics was relatively simple and cheap enough to allow entrants into its race. This was the era of "sealing wax and string" technologies, whose small experiments would yield large clues as to the internal constituency of the atom. Steven Weinberg, a main proponent of the multi-billion dollar U.S. supercollider, was shocked by its small size when he first visited Thomson's Cavendish Laboratory. Abraham Pais, another physicist who contributed to its devel-

opments in the post W.W.II period, identified 1900-1910 as mainly one of the small experiment. Necessary instruments included the vacuum tube, and Ruhmikoff coil, both of which were cheap and readily accessible. The pail-like cloud chamber had been invented as early as 1894, and the cyclotron was a small toy that could fit in the palm of one's hand. Unlike astronomy, which had entered the era of "Big Science" at this time, physics remained relatively accessible to the common practitioner. Science was "little" not only in terms of scale, but in terms of cost; the same might be said for its difficulty.¹⁴⁸ In a sense, true to the American value system, it was highly egalitarian.

The atom's mysteries were so poorly understood that ideology readily intruded into its assessment. It would take, for example, two years before the results of Thomson's experiments in 1897 were accepted; during a first reading, his amused British audience asked him if he was pulling their leg. German scientists who had even more accurately measured the energy to mass ratio did not even consider to postulate that its results were due to a corpuscle infinitely smaller within the atom; they were tied into an ethereal physical framework. As late as 1908 the anti-atomists would finally rest and accept a more complicated atomic structure, in part because of Einstein's work with Brownian motion. However, it should be mentioned that some historians disagree, and would shift this date even further to some four years or more after the 1PASC. The early beginnings of atomic physics were truly "religious" as discussed by Ravetz in that one needed some amount of faith to pursue one's research in light of so many unknowns. It was perhaps because of the intellectual uncertainty so characteristic of the "egalitarian" science that led Earnst Mach, a physicist, to postulate his now infamous positivism. One needed, Mach claimed, clear and distinct data, apparently harking back to Descartes' epistemology of the seventeenth century of "clear and distinct ideas". Yet, men such as Einstein would later abhor the thought, and believe Mach to have been a "deplorable philosophe." When the young Werner Heisenberg confessed to Einstein that he feared he did not have enough evidence, Einstein harked back that it was impossible to do much progress when one struck only to the evidence at hand. Smith would tactfully utilize this quasi-religious element in his rhetoric.¹⁴⁹

Smith began by describing a model of the atom, which at first seems somewhat akin to the plum-pudding model prior to Rutherford's work of 1911. What could account for the high e/m ratio discovered in Crooke's cathode ray tubes—was it an exceedingly high energy or an exceedingly low mass? The electron, or "corpuscle" as Smith uses, was exceedingly small. If it was about 1700 the size of the hydrogen atom, then did that mean that it had 1700 particles

arranged within it? It was hard to say. Smith then describes what seems to be surprisingly like the Bohr model of the atom developed in the same year as Rutherford's—concentric shells that hold only so many electrons to maintain stability.¹⁵⁰ Smith described how these different shells aptly described the periodic table. A central ring with only one electron, it would have to jump to another with six, then around this with eleven and so on and so forth for the atom to maintain a degree of stability. Although no one claimed that this theoretical model on a single plane was the actual state of the atom because it was a three-dimensional object, Smith believed there were “bastante semejantes” to form a notable conclusion. He also mentions that the, “depositos de energia interatomica se perciben inmensos, fuera de la concepcion y estan teoreticamente a nuestra disposicion.” Smith in 1908 had just suggested the potential existence of the atomic bomb and nuclear reactor, not unlike the seemingly clairvoyant H. G. Wells. Lastly, objects moving near the speed of light would gain mass by its interaction with the ether field. According to him, it was near miraculous how mathematics could trap the electron in mid-flight and force it to reveal its secrets.¹⁵¹

Smith then described the beauty of the electron as a unifying science in nature—as a means of making intelligible all scientific fields, from cosmology to biology. It was here where his religious argument began. Although it is not explicitly stated, it remains implicitly hidden in the background. As hinted at before, the new discoveries in physics did much to explain the properties of chemical components. All sort of natural phenomena in many diverging fields, Smith elaborately noted, could be explained from this new discovery: comets, solar corona, meteorites, protective function of atmosphere, aurora boreal, electricity, and in some cases even origins of life. Physical reductionism amounted to an orderly and coherent understanding of the universe.¹⁵² If we accept that the religious worldview is one that seeks an almost monolithic standpoint, Smith's able electron rhetoric provided such a view. The scientific element of Smith's lecture is thus underpinned by a religious motivation, which must have been very appealing to its audience and to the backers that had invited him to participate. It also serves as a backdrop against which he explicitly introduced religion at the end of his lecture. Science had actually proven religious truths, Smith claims. While discussing the impact of corpuscles on the origins of life, he wrote that the pre-Christian Gospels had predicted it. “¡Asombroso es tambien reflexionar que esta idea prodigiosa tan cuidadosamente abstraída y sostenida en cada punto por los pilares diamantinos del calculo matematico, habria sido anticipada en sus mas grandes proporciones por...las Escrituras de los Naassenes....”¹⁵³

Given his training in physics, Smith oddly placed religion at the uppermost of the value scheme. Although science was a construct, "esplendida y gloriosa...real [y] muy digna del estudio eterno", it could never be representative of an ultimate reality. For him, the world was but an idea that constantly changed. Despite the great insight and joy that was derived from science, the ultimate reality was spiritual. Man could always be fooled by nature, literally embodied by the hand of God and who constantly put barriers between men and absolute truth; "los productos mas brillantes de la investigacion fisica y fisiologica pueden probar ser solo trampas para nuestro pie inexperto". Should men feel that science was the ultimate goal of intellectual speculation, they would be fooled into an abhorrent and vacuous materialism.

Ironically, however, there was a certain complementarity created by this scheme between science and religion. Smith presented science as an unending quest that would never end, which was in a constant process of perfection. Smith was careful in valuing both the scientific and religious enterprise, constantly couching them in an epistemological complementarity. The religious element, explicit and implied, alongside a thoroughly scientific presentation must have had a great appeal to a predominantly religious community-stretching out to touch the hand of science.¹⁵⁴

Had William Benjamin Smith been the only attending delegate, the costs incurred by Chile would have been worth it. Despite his presentation's brevity, Smith had introduced physics while it was in the early throes of a revolution, and at a time when the technological and intellectual complexity of the field was still relatively simple. Its scientific state would have allowed many Latin American scientists to "jump on the bandwagon". But the opportunity seems to have been lost partly because of the IPASC's overly excessive ambitions. Had Smith been the only participating U.S. delegate, the importance of the topic might have been accentuated to its audience. However, he was not. Smith's presentation was buried in the blur of countless discussions, presentations, and social activities of the congress. Few visitors took notice of his work; it wasn't even given special mention in Poirier's *Resena* of the event. One wonders what might have happened otherwise.

3

Cepheid Variables and the Size of Latin American Physics:



Chile as a Case Study for the Role of Culture in Scientific Development

*“The richness of science no longer lies
in the abundance of facts but in their linkage.”*

—Alexander von Humboldt

What was the state of science in Latin America at the turn of the century? How did it compare to the North American science in the 1PASC that was reviewed in the previous chapter? Was it any less mathematically rigorous? Did poor instrumentation greatly affect its quality? Who was actually doing the research?

To answer these questions, scientific research is defined in this chapter in its most conservative form: it is “pure” as opposed to “applied” research. We want to know how much of what is traditionally considered science per se actually existed in the 1PASC that was locally made. How much “real” native science can we find; who was producing the most advanced works of Chilean science? We want to be the most advanced European or North American scientific researchers and judge the ideas presented solely by their scientific merit as set by the criteria of the era. Why should we assume this position? Again, because we want to categorically identify without any doubt any important science that might have been natively introduced. We are to be as ruthless and honest as most physicists are when debating with each other. Was there any original science at the 1PASC that would be considered worthy of a Nobel?

It is to these particular variables, the “upper peaks” as Vannevar Bush used to call them, which the historian must turn to in order to fully comprehend any region.¹⁵⁵ This might seem a bit harsh, but consider the alternative. It would be tantamount to describing the state of science in 17th century Europe by ignoring Newton! To do so would obviously leave a tremendous gap in the study, characterizing the historical analysis as incompetent at best. As in astronomy, we cannot simply take a “panoramic” view and believe these will faithfully represent our topic, like so many historical studies erroneously assume and do. Unfortunately or fortunately, we must use highly selective, perhaps even “elitist”, criteria to pinpoint the most useful sources historically speaking. Unfortunately, as the history of science shows, not all voices are equally valid.

While certainly applied science will lead to new discoveries, as has so often been the case in history, too broad of a definition would hinder this study. If an author at the congress was not trying to look for and present original research, then for all sakes and purposes he was not doing original research. We cannot accept a definition wherein attempts to increase the productive capacity of an enterprise accidentally led to side-results suggestive of original research. In this sense we are taking a highly “emic” view, unusual to most histories of science, in that we are using the scientist’s own personal intentions as one of our guiding criteria. However, in situating this work in its time, we must inevitably take an “etic” point of view; as Robert Merton would say, we want to take the “outsider” stance. While certainly understanding these ideas in their own terms, we must not accept any internal standards that might have hindered our understanding of nature had we lived in the era. This is just the goal science generally strives for, even if in practice it might be very difficult to attain.¹⁵⁶

Yet, which science to choose? Certainly, one cannot choose all; it would sorely test the knowledge of the historian and possibly jeopardize the merit of his conclusions. Because the quantum revolution is one of the most important and well-studied revolutions in our century, our primary target will be located within that science, physics. One should note that since physics affected a great number of other branches such as astronomy and chemistry, these will be touched on as well. Yet not only do we want to see whether the ideas that were introduced in physics by Michelson and Smith were readily adopted by the local scientific community, but also we want to identify the state of physics at the time. The two are mutually correlated.

However, if we were to try to identify progress in physics of all Latin American nations until, say 1920, our task would again become too difficult. It would be like trying to describe the growth of Newtonian physics in Europe during the

18th century in a few pages—“Europe” consists of many very different nations of many scientists that have to be treated individually before a general synthesis can be made. Unfortunately, Latin American histories of science have not grown as quickly as North American histories of science have in the last two decades.¹⁵⁷ Consequently, this study will limit itself to Chile, the host nation. That the majority of the 1PASC’s delegates were Chilean, and that the congress led to numerous local publications, makes both tasks that much easier for the historian.



As a whole, the amount of “pure” science, even in the volumes dedicated to “pure” science, was relatively scarce. For example, the volume dedicated to “Ciencias Físicas”, had a total of 22 authors of which only 7 can be categorized as pure science, while 15 as applied science.¹⁵⁸ Most of the former dealt with physics or physics-related phenomena while the latter dealt mainly engineering topics. The question immediately arises as to why the editors did not include these in the other two volumes dedicated specifically to engineering. While physics articles were typically very short, engineering articles were much longer. It thus seems that the volume would have been too slim relative to the entire collection, consisting only of about 62 pages, while most other volumes of the collection had on average 398 pages. Given the oversupply of engineering articles and their similarity to physics, there was a consequent “redistribution” to equalize the collection. However, had they refrained from doing so, it would have accentuated the importance and nature of physics in Latin America.¹⁵⁹

The “minor” authors, those who either summarized or had fairly poor essays, included in the relatively few “physics” studies will be briefly surveyed before going onto the more important expositions. Again, the emphasis will be on the work of local Chilean delegates.



William Benjamin Smith was not the only delegate who discussed the latest advancements in physics in the congress. A local doctor, Jose Ducci, did as well.¹⁶⁰ Like Smith’s presentation, it was not original research but rather a non-mathematical summary of that research in his time. Included in his lecture were descriptions of research on the electromagnetic nature of light, radioactivity, and Thomson’s *e/m* measurements. A chart presented the different *e/m* measurements for the rays then known: “Rayos catodicos”, “Rayos de Lenard”, “Rayos

ultraviolados”, “Rayos β del radium” and so forth. Unlike Smith, however, Ducci also spoke about physical chemistry, thus giving an expanded treatment on the implications of physics for other subjects. The work of Arrhenius, “Van’t Heff” (Van’t Hoff) and Rault in the 1880’s on electrolysis and ions were the first to be presented in his speech. Ducci’s presentation is significant in that modern physics was obviously not solely diffusing “externally” by U.S. connections but was diffusing “internally” within Chile as well.



Figure 11: Chilean delegates to Argentinean 1910 scientific congress¹⁶¹

Standing, l to r: Carlos Hoerning, Orlando Ghigliotto, Ernesto Maier, Jose del C Fuenzalida, S. Adeodato Garcia Valenzuela, Francisco Maradones, Ricardo Davila and Carlos E. Porter. Seated, l to r: Ricardo Larrain Bravo, Carlos Silva Cruz, Miguel Cruchanga Tocornal (Argentina), Santiago Marin Vicuna, and Alejandro Fuenzalida Garandon.

Despite Ducci’s awareness of the latest work in physics, he does not seem to have acquired the taste for original research while a professor at the Escuela de Ingenieria in Santiago. Typical to the nineteenth century Latin American scholar, Ducci was well versed in a wide range of fields aside from physics and medicine.¹⁶² His initial local recognition did not come about as a result of scientific experiments but out of literary endeavors; he later gained some notoriety for helping form a student’s union. We can say that much of his link to physics lay in his public expositions of its benefits to medicine. In 1919, he spoke on blood pressure and circulation, in 1922 on the application of electricity to medicine

(most probably electroshock therapy), and in 1925 on the use of x-rays. These, we should note, came after the IPASC, rather than before it. Ducci, incidentally, had been the editor of the volume dedicated to the “Ciencias Fisicas.”¹⁶³



Figure 12: Luis Riso Pastron and Jose Ducci.¹⁶⁴

Like Ducci, Victor Delfino also tried to present the latest ideas in physics, in particular with respect to electrical phenomena in a non-mathematical manner.¹⁶⁵ Unlike Ducci, however, Delfino limited himself to the unoriginal work of only one man. Delfino, likely a Francophile, was a correspondent to the Astronomical Society of France and described the work of M. F. Reen, member of the Belgium Academy of Science and professor at the “Universidad de Lieja”. According to Delfino, Reen’s *Prodrome de la theorie mecanique de l’electricite* (1903) was “destinada a revolucionar las actuales nociones sobre la genesis de la materia.” If applied to cosmology, “orientaia a los astronosmos hacia nuevas concepciones geneticas del infinito de los mundos...” The origin of planetary and stellar rotation would be explained by it. The theory was supposed to have the same impact in the scientific world as Newton’s corpuscular theory of light.

In fact, Reen’s ideas had long become obsolete, something that might have become obvious to the PASC delegates in light of the other presentations. He believed that electricity were “longitudinal pulsations” in the ether; it was not necessary to believe in corpuscular theory of electricity—“si la presion...es igual a la presion del eter exterior, hay equilibrio de presion y toda manifestacion electrica desaparece.” However, when a pressure differential was established between ether and matter, an electric charge was generated between the negative and positive “manifestaciones” in the two matters. No experimental evidence, no mathe-

matical treatment was ever presented in the very short exposition, which was given to a body of scholars, not laymen.

What was the problem with these ideas? Maxwell had shown that electromagnetic phenomena traveled transversally as opposed to longitudinally. Other presentations, as Mariano Gutierrez Lanza on, "Puntos de vista sobre los terremotos" had even mentioned this point.¹⁶⁶ Despite its theoretical benefits, ether could also never be tested, touched, or experimented on. This difficulty had troubled many physicists, including William Thomson who expressed his worries in a well-known 1901 presentation. How one would be able to determine "pressure" differentials is something of a mystery. Lastly, despite, all claims to the contrary, Reen's work was greatly based on a conceptualization of electricity in terms of fluids of opposing charges—an idea originating in the colonial times of Benjamin Franklin. Of all presentations studied by the author, this was perhaps the most unoriginal. The pomposity surrounding its claims only served to further denigrate the quality of the work.¹⁶⁷

There were certainly, however, other works which despite clearly lacking the rigor of a modern physics and originality of new data, certainly did reveal more of a scientific spirit. Some were initial inquiries, while others humbly presented evidence regarded as unusual and thereby meriting further study. Arturo Munnich's short "Un fenomeno observado por la fotografia en las nubes y de origen probablemente electrico" lacked any attempt at theoretical analysis.¹⁶⁸ It was uncharacteristically humble for this German immigrant, but it presented the "rare" phenomena of upward traveling lighting that he hoped would be further elucidated. The humble materialism is forthright.

In sharp contrast, G. L. de Llergo's, "Morfogenia: Ensayo sobre la generacion de las formas redondas de los cuerpos" was a very intellectually appealing study of the sphere in three-dimensional bodies.¹⁶⁹ Highly akin to D'Arcy Thompson's work, *On Growth and Form* (1917), Llergo looked at how different phenomena such as cells, water drops, low-pressure systems, and ropes tended towards the same rounded structure.¹⁷⁰ During the process of cell division, for example, the forces of surface area versus expanding internal pressure lead to the cell-shape, wherein "se establezca el equilibrio mas ventajoso."¹⁷¹ A teacher at the Escuela Nacional Preparatoria, Llergo reviewed theories such as Plateau's and Lagrange's to account for the similar mechanical processes that went on in these disparate phenomena. As Thompson did, he touches on the explanatory problems as to whether some biological phenomena are to be explained by heredity or by physical forces. It is important to note that while Thompson restricted himself to the biological world for its own sake, Llergo was more monistic in that he sought to

explain a broader diversity of phenomena within a more “unified” science. In other words, it was “idealistic”, emphasizing not only the natural world *per se* but on our ideas of it, a trait also found in W. B. Smith’s presentation. Its originality derived not from the discovery of new phenomena but from the synthetic treatment, which is what has made Thompson’s work a classic.

In sharp contrast, Arturo Munnich’s short “Un fenomeno observado por la fotografia en las nubes y de origen probablemente electrico” was acharakteristically atheoretical for this humble German immigrant. Lacking any attempt at theoretical analysis, it presented the “rare” phenomena of upward traveling lightning he hoped would be further elucidated. The humble materialism is forthright, including all the details—kinds of lenses, camera, and meteorological conditions—underlying the picture.¹⁷²

One minor author, neither from Chile nor wrote about physics *per se*, is worth describing because of the breadth of his presentation. Already mentioned, Mariano Gutierrez Lanza’s survey of scientific research on earthquakes was monumental not only because of its size, but also because it described the latest research.¹⁷³ Taking up seventy-six pages of very small fine print, it could have stood as its own volume. What is perhaps surprising is that the author was Cuban, Sub-director of the “Observatorio del Colegio de Belen.”

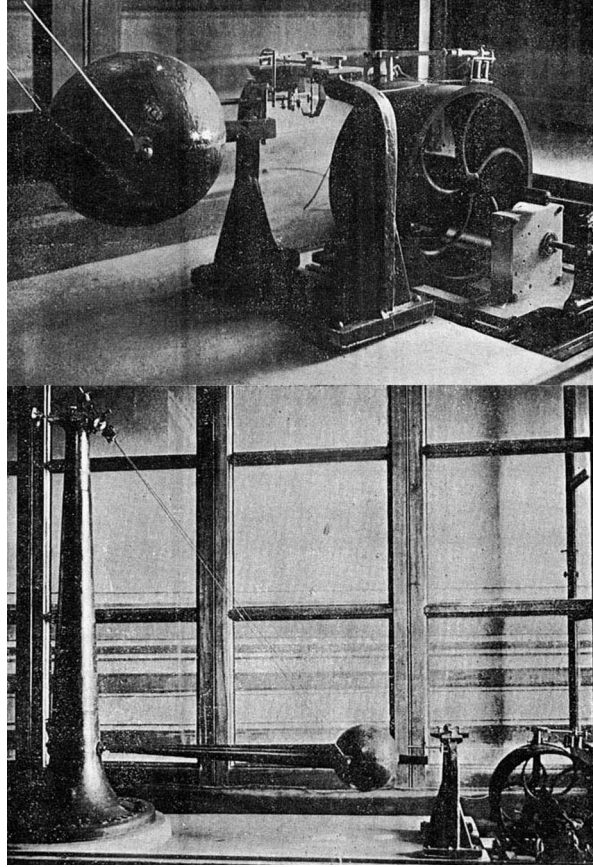


Figure 13: "Modern" seismograph in Colegio de Belen, Cuba ca. 1908¹⁷⁴

Gutierrez explained that the science of seismology, although in its infancy, had made tremendous progress in the last few decades. As late as 1875, the science understood little of its dynamics and was mainly restricted only to a descriptive science. With its evolution, better understanding had been gained of the causes and factors involved, and had clarified many previous misconceptions. For example, earthquakes are actually not motions perpendicular to the plane of the Earth but rather parallel to these. If one compared the horizontal and vertical axes of movement, the latter was proportionally minuscule and could only be felt in the largest of earthquakes. The maximum acceleration of movement was deter-

mined by formula: $\beta = 4\pi^2 a/T^2$. Not unlike work on the electron, the physics of earthquakes had been developed only by indirect evidence, such as “lo que tiene lugar debajo de la tierra, que no se ve ni se siente...es totalmente objeto de inferencia.”¹⁷⁵

Yet the actual movement of waves within the Earth was not fully understood, Gutierrez explained. Theoretically, the first shock should be felt, followed by a long silence and then secondary shocks. However, it is known that earthquakes have aftershocks that “se sigue sintiendo por horas enteras sin interrupcion, aunque el centro de accion haya durado pocos segundos.” It was also known that the path of these waves could be modeled according to the formulas for the propagation of light or sound waves, $V = \sqrt{E/D}$, where E was the coefficient of elasticity, and D the density of the medium. However, which model for the Earth should be used—whether a homogeneous, heterogeneous, or a body with multiple variations of density—could not be determined. The calculations were far too complex because these variables were not known. It was certainly known that waves spread concentrically outward throughout the entire sphere of earth, but exact predictions were still long off in the future. Thus, fact and theory did not match, not unlike existing problems in thermodynamics.¹⁷⁶

The problem of the “earth’s internal shape” would not be resolved until the mid 1920’s, a decade after Gutierrez’s presentation. Until the 1890’s, the idea that the earth had a relatively liquid inner sphere were predominant, until work of physicists began to cast doubt and reversed this model to one of a mainly completely solid inner core. In 1909, however, anybody who questioned William Thomson’s solid model risked damaging his scientific reputation. That year, the President of the Geological Society of London stated, “Thus, through the shifting sands of an ancient and prolonged controversy, *terra firma*, indeed *terra firmissima*, has at length been reached.”¹⁷⁷

We may thus note that Gutierrez, in contrast to many British colleagues, was very firm and honest in his candor as to the ignorance within his field of study. Just because a scientist was located at the periphery did not necessarily entail an intellectually subservient attitude. Gutierrez, unfortunately, falls into a rather backward scientific tradition—backward because he all too typically sought to be comprehensive without being original in a much more limited terrain. Gutierrez did not have that necessary virtue of the scientist identified by Michael Polyani, intellectual humility, thus we may categorize Gutierrez in the lesser position. Scientists can be gods because they recognize their own frail humanity.

We may thus note in this brief summary of minor authors that there was a great deal of diversity between them. Not all minor works were to be dismissed,

and some attempted to genuinely grapple with topics in a scientific manner characterized by a material and empirical outlook. A nascent scientific worldview was thus making itself felt at the time by native Chileans. They were becoming “scientific”—an important and worthy historical fact. It is somewhat disappointing, however, that so many presentations were merely reviews of existing work. One certainly might attribute this to the lack of a general “research ethic,” but it is perhaps more appropriate to contextualize it in light of the fact that Chile, as most Latin American nations, did not have a strong scientific tradition—a pattern that has continued onto the present day.¹⁷⁸ It would thus be natural, given the circumstances in which local scientists operated, to present these broad pictures of the leading boundaries of contemporary science. Only in this manner, could a scientist more appropriately situate himself in the contemporary scientific context, and thus proceed on to new ground. Such summaries were stepping points on to the terra firma of science.

Had similar efforts been conducted previously, the “major” authors might have avoided redundancy of work, and it is more likely that they would have contributed much more significantly to this leading edge given their skills and talents. It is towards them that we will now turn. Regardless of whether they did or did not contribute to the science of their time, the quality of their work was outstanding relative to that of their Latin American colleagues. The general attitude, method, and mathematical rigor of these major players was even not that much different from the physicists of today; the differences are not qualitative but quantitative.¹⁷⁹ Exactly how exactly these local major players situated themselves in the world of modern science will be the subject of the next section.



Who were the major “native” scientific players?

In an old 1970’s article for *The New Cambridge Modern History*, Charles Griffith wrote that while the French influence was predominant throughout Latin America in terms of cultural tastes at the turn of the century, Germans had made strong inroads into influencing public education. Latin American creativity did not manifest itself too greatly in most of the arts, with the exception of literature. Griffith’s comments remain generally valid for our broader topic: science.¹⁸⁰

The major players representing Chilean science at the 1PASC were usually either of French or German descent. Studying in the leading centers of European science, these men brought with them to Chile the latest science, in a process not unlike the international transfer of mass-production techniques during the Indus-

trial Revolution—the relocation of an individual meant the transfer of a particular knowledge base.¹⁸¹ It should be noted that the first decade of the century reflected a clear shift from French to German scientific influence in the region, as suggested by Griffith. This can be observed in the *Anales de la Universidad*. While the French influence in the journal was negligible, German scientific articles were clearly predominant between 1890 and 1910. As such, the 1PASC was a harbinger of transition—we see the declining pinnacle of French influence and its emerging “rival”.

The two most important physics authors at the 1PASC were French. Alberto Obrecht described at the 1PASC new ways of determining the figure of the Earth, a problem in geophysics, while Marcel Lachaud spoke on the problem of specific heats in thermodynamics. Other important presentations were by the Germans Luis Z. Zegers and Federico W. Ristenpart, who discussed electrolysis and solar eclipses respectively. Of the four, the first two were the most important in that they were honest attempts to resolve scientific problems of the day. Ristenpart had only recently arrived to Chile that year and gave only a brief presentation of data he had accumulated on a trip to Argentina a few days earlier, while Zegers’ presentation was on applied research and thus outside the immediate scope of this chapter.¹⁸²

Surprisingly little has been written about these men; Chilean cultural-intellectual biographies seldom mention their names.¹⁸³ Obrecht is perhaps the best documented of all. Born in Strasburg (France) 1859, he arrived to Chile in 1888, soon becoming Director of the National Observatory—a position he held for about thirty years. He had also been president of the Chilean Scientific Society between 1891 and 1898. Obrecht had studied at the Sorbonne Polytechnique.¹⁸⁴ Ristenpart, who was hired in Germany to succeed Obrecht as Director in 1908, was obviously of German descent, but that is all to be learned of his background.¹⁸⁵ Lachaud appears nowhere. One may gather that he was likely an industrial chemist who lived in Chanaral, Chile—a coastal town between Santiago and the northern border.¹⁸⁶ The relation between his 1PASC topic and profession would not be unusual in that kinetic theory had revolutionized the practice of chemistry in the last half of the nineteenth century. His chemical outlook is also revealed in his theoretical approach. Aside from this evidence, that is all we know of the man, something unfortunate given that he was perhaps the most important figure in the entire congress.

A question immediately arises with regard to the nationality of these men. Were they Europeans or were they Chileans? The question is not as easy to answer, as it might first appear to be. All of these men theoretically represented

Chile in the congress, yet obviously their degree of allegiance to the nation varied greatly. They were not “Chileans” strictly speaking, but were they necessarily “European”? Their identities varied greatly. While Ristenpart could be considered at one end of the spectrum, Obrecht might be placed in the other.

As a whole, we can characterize the German community as one that tended to retain its cultural identity intact, as the Jewish had done in Germany. They formed specific German societies, wrote books specifically from a German viewpoint, and coalesced within particular regions of the nation. The Sociedad Científica Alemana de Santiago, for example, had its own local journal, the *Verhandlungen des Deutschen Wissenschaftlichen Vereins* written solely in German. This amount of reclusive activity, including that of the scientists, naturally aroused a degree of local resentment. Men like Eduardo de la Barra, a Chilean linguist and literary scholar, wrote a scathing critique of the German scientific influence in *El Embrujamiento Aleman* (1899).¹⁸⁷ Zegers was one of many who were subject to these attacks.¹⁸⁸ Most educational leaders as Letelier and Barros Arana, however, felt otherwise. Yet Ristenpart easily fit into this category in that he was “pro-German”, publishing an essay on German astronomers for the Sociedad’s *Los Alemanes en Chile* (1910). A listing of his works also show that Ristenpart published mainly in German rather than in Chilean scientific journals while living in Chile, the *Astronomische Nachrichten* being a common one.¹⁸⁹ In 1910, only 3 of his 13 publications were in Chilean journals, while in 1911, only 4 of 15; although more were listed in Spanish language in the latter year, the ratio remained the same. It is curious to note that most German teachers hired for Chilean high schools did not usually remain in Chile after the end of their contracts, in sharp contrast to Rowe’s appraisal of German “cosmopolitan” behavior.¹⁹⁰

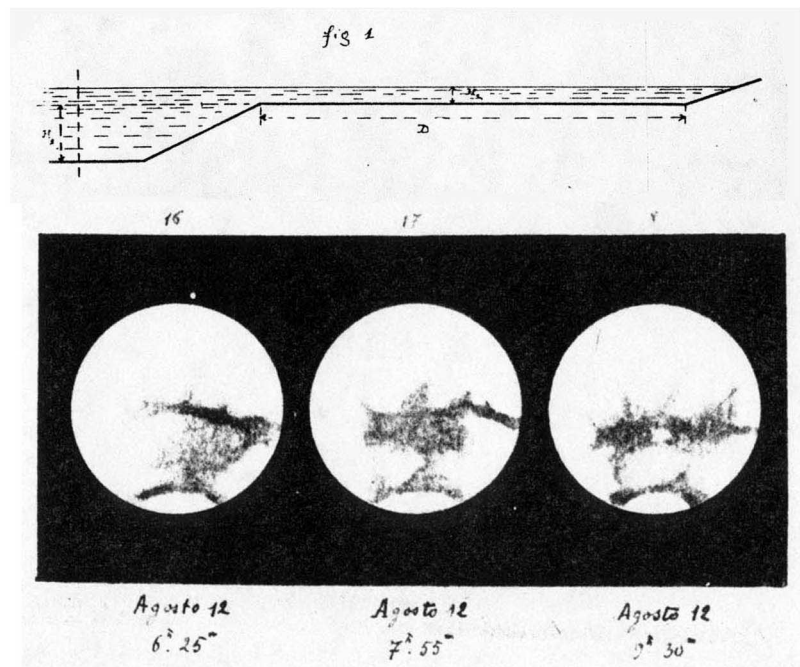
A review of Obrecht’s works does not reveal the same sense of metropolitan identity as Ristenpart’s. Obrecht seems to have published very little in France. Most of his scientific work was conducted for and in Chile, in particular the *Anales de la Universidad* which included the vast diversity of his output: cartography, meteorology, mathematics classes, astronomical theories, and so forth. We might note that his emigration occurred at a relatively early age, when he was 29, and remained there the rest of his productive life. (His sister, had also moved and translated there as a professor.) This stands in sharp contrast to Ristenpart who relocated as an older man, already well established in his personal life. Obrecht thus seems to reflect a pattern more common throughout the nineteenth century—European scientists who moved to Chile and made it their homeland, marrying, and raising children, and dying there. This was the case for R. A. Phil-

ippi (German), Ignacio Domeyko (Polish), and others. Whatever their origins might be, the locale of an adult's productive life will certainly indicate which nation will benefit from these services. This is as much a result of circumstance as it is of individual choice as the biographies reveal.¹⁹¹

There was some degree of personal animosity between the two, but it appears to have been one-sided. Ristenpart, alluding to Obrecht, claimed that “Solo mencionaremos, que en los 21 anos de su directorio no se ha observado el reglamento del Observatorio, como tampoco se hizo en los 22 anos anteriores.” He seemed to consider Obrecht an “incompetent” who had not done what he could to advance astronomical knowledge.¹⁹² While Obrecht might at times be characterized as such, it is somewhat of a malicious characterization. Obrecht recognized that local circumstances could not be the same as those in the metropolis (Paris), and adapted as best he could to given circumstances. Although he called for greater personnel and instrumentation, he recognized that it would be unlikely that his research needs would be met. He suggested the formation of an astronomical school for the training of Chilean astronomers because there were few individuals trained in the needed skills—a suggestion which was ignored by the government.¹⁹³ Ristenpart, on the other hand, was “fired” from his position because of increasing demands on the government. The fall of Montt and Ristenpart's acerbic behavior likely led to the non-renewal of his contract, and his consequent suicide. Obrecht was certainly the more even-tempered of the two.

The differences in their personal character are quite apparent, and a comparison of their tenures as Directors is interesting in elucidating the different character of their “metropolitan” science. We may get a hint by noting that, while Obrecht's report as director emphasized the many practical benefits; Ristenpart alluded to its potential astronomical value as his selling point. These psychological and social elements intertwined and affected one another.

Obrecht's function as director was much more closely related to that of a nation in need of development; it was closely tied to the heart of Chile. A much greater part of his works were dedicated to “practical” studies while Ristenpart seems to have been more concerned with advancing astronomical knowledge per se. The mapping of Chile was essential, and Obrecht's early work was concentrated on this task. Obrecht had been in numerous commissions created for the accurate mapping of the nation since his arrival.¹⁹⁴ The pages dedicated to practical meteorological data fill the observatory's publications in the *Anales*.

Figure 14: Obrecht's canal design and drawings of Mars¹⁹⁵

We may observe this practical orientation also in the 1PASC, where Obrecht analyzed the most suitable canal design in the region of Llico.¹⁹⁶ Putting mathematics to work, Obrecht realized that the changing tides would create enormous velocities in the canal if built according to the same specifications as the Suez Canal, initially a French endeavor. At Suez, the distance of canal was 30 km, while area of lake was 20,000 hectares; in sharp contrast, the distance to be covered at the Chilean site was 5 km, which emptied into a 1500-hectare lake, “lago Vichuquen”. The higher tides, the shorter canal, and the smaller body of water into which it emptied would create velocities that would thrash boats uncontrollably about. A much wider and deeper canal was needed; Obrecht showed exactly by what quantity and in what amount. Obrecht used Bazin's formula, $V = k\sqrt{(R I)}$ ¹⁹⁷ to derive the current's maximum velocity, given by the equation: $V_{\max} = (a m S/\Omega)(dy/dx)_{\max}$. His mathematics was not radically new, but it certainly saved the Chileans a great deal of hardship, something that should not be overlooked.

Yet, it was not that Obrecht wasn't concerned with issues related to pure science. Some of his papers, as his 1892 study of the canals in Mars, dealt specifi-

cally with astronomical questions of the day. If Campbell at the powerful 76 cm Lick had been led to reject Shiaparelli's ideas of 1888, Obrecht at the small 34 cm local observatory accepted its conclusions hesitantly. "Es mui difícil desaherger por completo de ideas preconcebidas en tales observaciones. Varias veces he creído distinguir perfectamente algo parecido a canales, cuando no veía en realidad sino la imagen de mis pestañas sobre el disco del planeta."¹⁹⁸ He tentatively accepted their existence, but acknowledged that he would not fully believe these until he had clearly observed them with his own eyes. Obrecht also tried to advance astronomical methods of determining solar eclipses. Relying primarily on the work of Bessel, his methods were not new but rather more effective.¹⁹⁹ He calculated the path and time by which the moon would traverse the sun's image as seen in Santiago. In other words, his mathematical skills showed the Chilean public in 1892 how the two solar eclipses would be seen in 1893—something which surely must have received some amount of admiration.

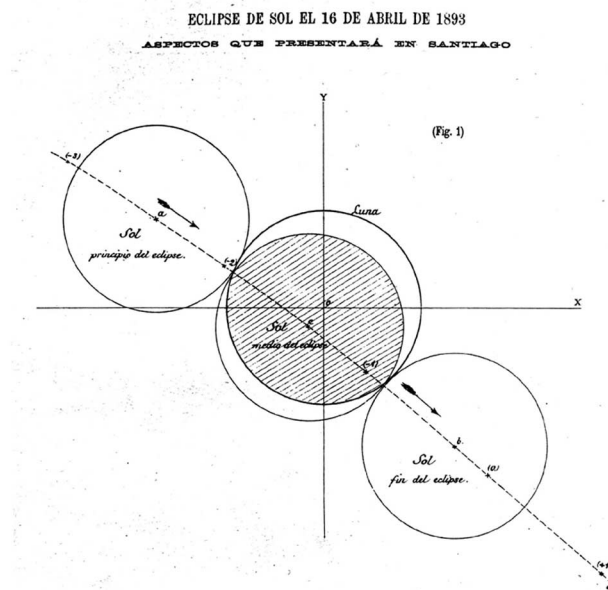


Figure 15: Obrecht's calculations solar eclipse²⁰⁰

In sharp contrast to the general character of Obrecht's work, Ristenpart anxiously wanted to advance the known boundaries of human knowledge. Astro-

nomical laws were not exact enough, Ristenpart explained at the 1PASC. The 1905 solar eclipse had taken everybody by surprise because theoretical predictions had been off by 15 seconds. The three-body problem concerning lunar-solar-earth movement which at a point had raised questions about the Newtonian system, continued to plague astronomers of his day. Ristenpart had actually traveled to Argentina over a long and difficult terrain of 4,000 km, many times walking on foot across the Latin American Alps, to get a better view of the full eclipse, which would not pass directly above Santiago where the observatory was situated. Carrying only a few instruments, a 7cm Frauhhofer equatorial and three “anteojos”, he found that the first interior contact had 21 seconds of anticipation, while the second interior contact was preceded by 19.8 seconds; exterior contact differed by 1 and 15.5 seconds respectively. He hoped that this new data, which formed the core of his 1PASC presentation, would help resolve the problem.²⁰¹

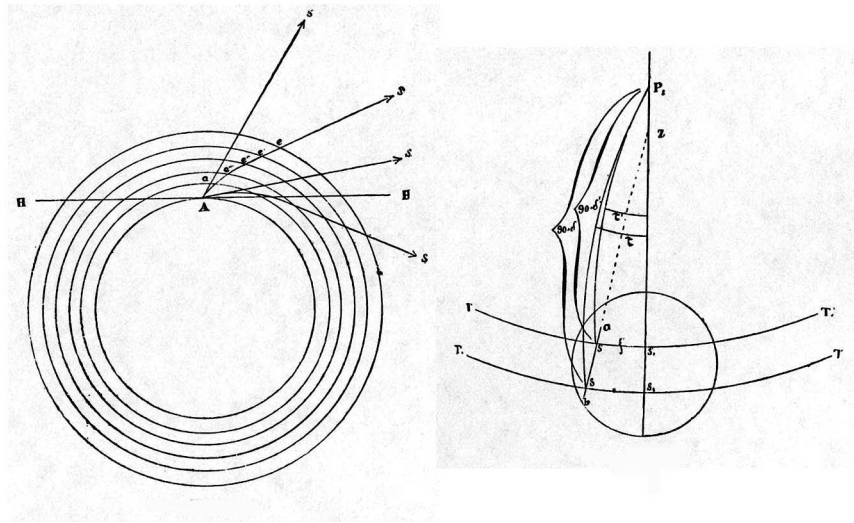


Figure 16: Ristenpart’s class diagrams²⁰²

To many Chileans, this demand for rigor, 15 seconds, must have seemed a bit extremist. For Ristenpart, however, it meant a weak science to be remedied; in the eternity of universal time, minor differences would eventually amount to grave irregularities. If man were to hold nature in his mind, he would have to be more accurate within his very short lifetime. Ristenpart was quick to criticize those, including his German colleagues who did not abide by these standards.²⁰³

Yet we may also observe that not only the detailed minutiae, but also the institutional and cultural changes which needed to occur in order to do leading research must have been a tremendous source of friction between Ristenpart and local Chileans. If Ristenpart wanted to abide by his goals, this necessarily entailed a local departure from the accepted procedures. To “raise the highest peaks”, he needed to quickly raise local standards at a relatively fast pace. This is precisely what he did, but it is very likely that it further worsened his relations with the local Chileans. The autocratic character needed for such a goal, and the apparently uselessness of such a goal must have not made a best first impression to the non-scientific nation.

Upon arriving, Ristenpart streamlined operations at the National Observatory and shifted it into a higher gear, picking up its pace. New heads were installed. Dr. Walther Zuhellen was placed in charge of “astrophotography”, Dr. Richard Praeger in charge of “calculations”, and Richard Wüst, of the Zeiss firm in Jena, as instrument supervisor—all obviously of German descent. So many stars were measured in that first year, 17,000, that new human calculators were added. By the end of 1910, the observatory had grown by about 14 new staff members, including five “calculistas” (mainly female), three “fotografos auxiliares”, and one “ayudante de seccion de los Meridianos”. That same year, the budget was increased to 81,400 gold “pesos” and 105,000 “pesos papel”. Instrument parts that had previously been damaged were replaced. Ristenpart brought a Gautier diffraction grating and Zuhellen a Respsold. The observatory’s meteorological duties were eliminated, and an electronic, as opposed to sound (a cannon), means of determining the hour was instituted. In 1911, the Observatory made something like 1439 “observaciones de pasaje” and 1388 “lecturas de circulo”. Dr. Praeger plotted 200 nebulae in the southern sky, and compared 38 nebulae with “estrellas comparatorias”. There were 192 observations of “pequenos planetas” made, including Iris, Massalia, Hestia, Sappho, and Anahita. Work was coordinated with Argentinean astronomical centers for the observation of Halley’s comet. The observatory also was to be relocated to a region further away from the city, and would publish its own journal in 1912.²⁰⁴ Ristenpart would also get into a great deal of conflict with the government over the location of railroad lines nearby. In contrast to Obrecht, who fatalistically accepted personnel, budgetary, and instrumental restraints, the pace set by Ristenpart was fast indeed.²⁰⁵

Yet, despite their differences, both Ristenpart and Obrecht shared the need to make astronomy accessible to the public; it encouraged government support and public funds. Ristenpart, for example, gave a very moving lecture on Halley’s comet in April 1910 in the main hall of the university.²⁰⁶ There apparently had

been some amount of public disorder because it was believed that the tail, which contained traces of cyanide, would cross the Earth's path thus killing a large number of people. Ristenpart reassured his audience that not only was the comet on another plane, but that it was too far away, 32,000 km; its 12,000 km tail would not strike the Earth. Even if it did, these would burn up in the atmosphere. The main emphasis of the lecture, however, was a mythic appeal to the heavens. Imagine if, like the goddess Cipher, one could return every 500 years and witness the rise and decline of human civilizations—this exactly is what comets were. He wryly noted that while the U.S. financial elite freely gave sums to science, their South American counterparts were much less philanthropic. Obrecht similarly brought astronomy to the public, but in a slightly different manner. All of his publications contain backbreaking detail allowing the reader to exactly recreate the work involved.

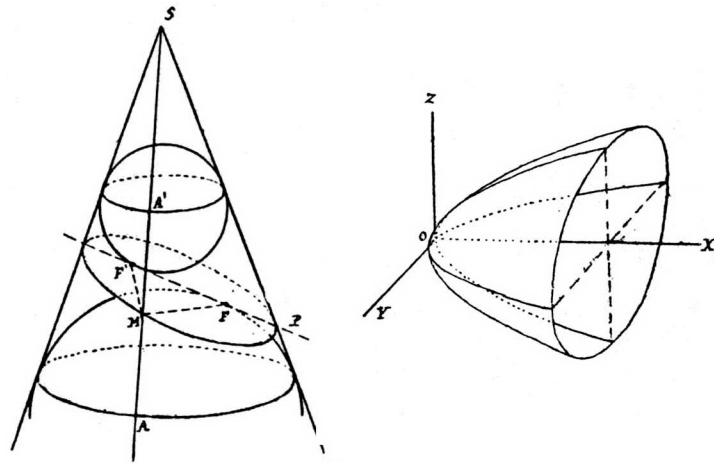


Figure 17: Diagrams from Obrecht's calculus class²⁰⁷

Both men also taught mathematics courses, which were formally published as books. Ristenpart explained that he had done so because poor copies were being disseminated, “demostrando en las partes teoreticas las ignorancia del plajiaro.” He mentioned that the government had forced him to publish his lectures by stipulating it in his contract—a fact he widely but perhaps tactlessly conceded.²⁰⁸ Both men's lectures demonstrate how similar the scientific methods were to our time. While Ristenpart's treatise dealt with instrumentation, and thus was subject

to faster obsolescence, the principle underlying sources of aberration remain fairly much the same today: changes in pressure, temperature, refraction of light, and atmospheric disturbances. Obrecht's calculus lectures are almost identical to modern calculus textbooks. While modern textbooks include a much wider variety of topics, Obrecht's lectures seems to have been designed specifically for the astronomy student. They are less bogged down with minutiae and detail, and they show greater concern for simplicity of principle and explanation. As such, they fit well with German criticism of the Chilean educational system, that it was too fragmented and disunited. Students learned a great many topics with no apparent cohesion or relation—a criticism that can also be made of today's U.S. high school science education.²⁰⁹ A greater portion is also dedicated to astronomical related phenomena.²¹⁰ It is, however, surprising that, like modern textbooks, Obrecht does not dedicate greater time to the practical benefits and uses of the calculus. Given the pervasive derivatives and integrals that allowed him to conduct his practical work, one would think it would have been otherwise. In both cases, however, the student learns abstract ideas which are so removed from reality in that they tell him nothing of the full range of applications nor of the actual nature of the world; "atonic faces", as Ziegler called it, were the likely result.



If North Americans sought to spread the gospel of science, they did not succeed in spreading its spirit. One predominant character of North American presentations was that they mainly presented results. Little of the scientific skill and intuition that actually went into attaining these results are revealed. Curtis provides the raw data. Smith describes the latest theories. Michelson shows how to construct. Nowhere do we find how the theories were developed, in what ways the instruments could be most appropriately used, nor how the raw data could be correctly interpreted. To some degree, they either presumed a scientific background or that it would be acquired at some future time. How those skills were to be acquired was none of their business. Perhaps appropriately so. As leading scientists they were interested in pushing further the "highest peaks", not in "leveling the playing field". However, it could not have been more different for the French presentations.

Lachaud and Obrecht reveal in full detail every step of the way. They present their assumptions, the hypothetical model they are using, and the logical steps taken to arrive at a given result. Regardless of whether their results are correct or not, we genuinely observe the scientific mind at work. This is not to say that they

are always necessarily original. Obrecht, for example, in two of his presentations gave a rather summary exposition of the calculations of tides and the elimination of statistical error from data sampling.²¹¹ Yet, in his theory on the shape of the Earth and in Lachaud's on specific heats, we observe the beauty of man's attempt to grapple with nature. How are we to understand her? She is difficult of comprehension and eludes our gestures. We observe the attempt to break down the barriers separating man from his world.

Although both topics were important, Lachaud's was the more scientifically relevant. The problem of specific heats had long plagued thermodynamic theory; there was incongruence between prediction and outcome. If we assume that matter obeys Newton's laws, then theoretically we could predict its different properties on a "matter in motion" model. The mathematical ideas of Rudolph Clausius, James Clerk Maxwell, and Ludwig Boltzmann provided the underlying structure for such a model. The problem, however, was that while the model was appropriate for gases at normal temperatures, it did not work for diatomics as oxygen outside a certain temperature range nor for certain solids with a high crystalline structure like diamonds. They did not act as they were theoretically modeled to act; they were "aberrant" anomalies. Unlike psychology or psychiatry, however, it was not that the agent was unusual but rather that the theory used to view these needed to be amended. The quantum revolution, in particular Einstein, would eventually reform the physical theory underlying this specific problem. It is important to note, however, that Lachaud, by attacking the problem of specific heats in 1908, was directly confronting one of the most serious difficulties in the physics of his day.²¹²

Let's, however, begin with Obrecht.

Initially, Obrecht did not present his ideas as a radically new method. Observing the differences between theoretical calculations of ellipticity, or the degree to which one axis is shorter than the other or $(a-b)/a$, and observed results, he believed he was merely presenting a more effective means of resolving the disparity. Theory yielded $1/231.7$ while observation gave $1/293.5$ for the Earth; similar problems existed in the case of Jupiter and Saturn, the largest planets in the solar system. Yet in contrast to his "De la figura de los planetas" at the 1PASC, the small volume, *Nueva Teoria de la Figura de los Cuerpos Celestes*, of 1914 made the claim to originality in a much more open manner. Although the physical assumptions slightly differed between the two, the mathematical work remained fairly much the same. His first work relied on Plateau's work on capillary forces in a membrane, while the second presumed the surface forces to be affected by very

thin free-floating solid shells. In both, he relied on the model of a rotating fluid body, with the same accompanying formulas.²¹³

“[S]e puede buscar la forma exterior de una masa liquida...suponiendo que los puntos de la membrana hipotetica que limita el liquido estan sometidos...a una presion normal constante, y a la fuerza de inercia del movimientno de rotatcion.” Taking this as his physical model, Obrecht derives a series of equations to calculate the resultant form. Initially he finds it for the Earth and later develops a more general formula for all the other planets. One variable that obviously could not be determined was T , or “la tension de la membrana en los polos”. Not unlike Maxwell who could not account for the total number of molecules (N) in his velocity distribution law, Obrecht proceeds to eliminate T . He finds out that T is not only equal to $a/2 (P + pw^2a)\cos\theta$, but that it is also equal to $x/2 (P + pw^2x \cos\theta)$. This frees him, and allows him to obtain the values for respective “puntos nulos”. He finds that as the series of alpha remains at a small value, the formula for ellipticity applies. Other comparisons lead to a more generalized formula for ellipticity: w^2a^3/fM . Obrecht then observes that the results are much more in agreement with accepted values, thus likely strengthening the validity of his mathematical approach and physical model. For earth, the result was 1/290.7; for Jupiter it was 1/13.4 (observed was 1/17.1) and for Saturn it was 1/8.1 (observed was 1/9.2).²¹⁴

But was he right? Unfortunately perhaps, he was.

The problem of the Earth’s shape, whether shaped like an egg resting on its side or bottom, had become of central concern to eighteenth century physicists; a sort of “specific heats” problem of the day. Its resolution would help to either verify or undermine Newton’s work. Curiously, it was not his British compatriots who succeeded but the French, particularly Alexis Claude Clairaut. A boy genius, Clairaut had accompanied Maupertuis in 1736 to Lapland to measure the Arctic Circle. Another expedition, led by La Condamine, had gone to Peru for similar readings at the equator. While Maupertuis measured 54,941 tortois, La Condamine obtained 56,475. Although the observations justified the theory, there remained a great deal of work regarding the dynamics of a rotating fluid. Clairaut, while advancing hydrostatic theory, resolved the difficulty of its application and published his results in his 1743 *Theorie de la Figure de la Terre, tiree des Principes de l’Hydrostatique*, which gave full validation to the Newtonian system. Clairaut had mathematically proven that, indeed, the Earth was an egg lying on its side.²¹⁵

Certainly, there were many other men involved in such highly complicated mathematics. Pierre Simon Laplace, in the third volume of his *Mechanique Celeste* (1802), slightly improved Clairaut’s work. However, Clairaut had laid the

fundamental model that has received only slight relative modifications since then. Laplace so respected Clairaut, that he wrote, “L’importance de tous ces resultats et l’elgance avec laquelle ils sont presentes, placent cet ouvrage au range des plus belles productions mathematiques.” Curiously, both Laplace and Clairaut claimed that the problem could not be resolved using capillary as a hypothetical model, “cette theorie me parait insignifiante.”²¹⁶

There were a number of differences between the Obrecht and Clairaut.²¹⁷ It should be noted that Clairaut did not express his ideas in the same mathematical form as Obrecht. Although certainly the founder of such principles, its modern expression seems to have been developed later in the century (1793) by D’Alembert, who so unfairly criticized Clairaut.²¹⁸ Nonetheless, it should be noted that the general resolution seems to have been largely the result of the high state of French science of the eighteenth century—in very sharp contrast to the state of French theoretical physics of the later nineteenth century.

A number of questions are immediately raised.

Why didn’t Obrecht, who had received his mathematical training in France, know of Clairaut? It was certainly not that Obrecht plagiarized. He clearly gave full recognition to predecessors, such as Plateau, Bessel, and others, throughout all of his papers. More importantly, why wasn’t he informed at the 1PASC that the work had already been done? While the first is more easily understandable, the second is less so.

Textbook training only gives general skills, it is obviously not meant to be encyclopedic. Recent graduates only obtain the intellectual maps enabling them to explore new territory. Given the limitations of resources, funding, and time available, the vast range of applicability cannot possibly be covered in this training. As the young scholar teaches and conducts research, he comes to more fully appreciate the depth and applicability of these skills, which will hopefully be reflected in a more encyclopedic view as a mature scholar in his later years. However, we should note that the time of study, while certainly more concentrated as a formal student, is significantly vaster after a scholar has graduated from schooling. Simply put, “you learn more out of school than within it.”

It is somewhat thus fairly easy to hypothesize why Obrecht, who had traveled to Chile as a young man, had not been aware of his national predecessor’s work. The likelihood is that while he might have been briefly exposed to it, he might have either easily forgotten it, or passed on to other more immediately necessary topics such as cartography. Once arriving in Chile, given the bibliographic limitations and the general lack of a serious astronomical tradition, there would have been very little means for him to become aware of it as a practicing astronomer.

That he became “nationalized” likely meant that his ties to France were severed, thus further hindering his ability at bibliographic verification. The colonial scientist is always at a disadvantage because he does not have the ample resources, institutional and intellectual, which surround the metropolitan scientist. Would it be otherwise, if we could plop these institutions in the periphery, there would theoretically be no difference between the two. The differences generally lie not in human skill but in the broader institutional environment. Although Ristenpart’s critiques of Obrecht may have been valid from an “internal” point of view, from a “regional” point of view they were malicious and unjustified.²¹⁹

That Obrecht honestly believed his theories to be original in 1914 certainly proves one point: nobody at the IPASC told him that they were not.²²⁰ This is highly troubling because the purpose of the IPASC was to have been an “honest and forthright exchange”, as Root counted on to improve his diplomatic efforts in the region. Scientifically speaking, however, it seems that the mixture of diplomatic goals severely hindered its primary goals. Perhaps fearing potential conflict and be perceived as insulting, North American delegates reservedly withheld their opinions. The negative effect of these diplomatic efforts on science is further raised to the fore when we consider that Curtis, the principal U.S. representative of the astronomical community in that congress, generally liked a good argument. He had been trained in the classics, which tended to stimulate such exchange and explained why he was a leading spokesman in the field.²²¹ It is interesting to note that Todhunter’s historical survey of the topic had been published in 1884 in London, and thus available to the North American audience.

What about Marcel Lachaud?

As he well recognized in “Rapidez de translacion de las moleculas gaseosas”, Lachaud assumed a purely kinetic model. Oxygen molecules were points that collided with one another to give the gas its characteristic properties. “Estas moleculas recorreran trayectorias sensiblemente rectilileas, hasta que un choque con otra les obligue a cambiar la direccion. Se asemeja a lo que sucede en el juego de billar...”²²² There was a problem with the kinetic assumptions because the predicted speeds given by the model did not match the observed speeds. While the theoretical average speed of oxygen molecules should have been 460 meters per second, the experimental speed was determined at 580 m/s. Lachaud’s aim was to resolve this disparity, to get rid of the anomaly. This is what he did, literally; he calculated out of existence the anomalous differences.

Lachaud worked backward instead of forward, perhaps because he was a chemist. His approach was nearly identical to the one used by Ostwald in the late 1870’s to evaluate affinity constants.²²³ Beginning with the known physical prop-

erties of the gas, after numerous calculations he derived four different sets of figures for the expected molecular velocities. Knowing that sound traveled in oxygen at a temperature of 0° at 314 to 315 m/s, he calculated that the maximum speed of oxygen molecules was 628 m/s and its minimum was 560 m/s, giving a probable mean value of 578 m/s—much closer to expected value. The method by which he did this was vector integration: $\int (2\pi \cos\theta \sin\theta) / (2\pi \cos\theta) d\theta$ which showed that the molecules must be traveling at almost twice the speed of the sound wave.²²⁴ Other procedures, all however based on “el calculo de las probabilidades”, were applied to the different properties of oxygen gas: weight, pressure, and specific heat. Respectively, the results were as followed: 588.5 to 567; 583 to 576; and 591 to 577. Since all were within the expected ranges, the kinetic model had been rectified.

Was he right? No, he wasn't. Ironically, however, this is his virtue.

As some might have already realized, it was not that Lachaud's mathematics were necessarily wrong, but rather that the assumptions in which he couched these were incorrect. Lachaud obviously did not rely on any new experimental data, but rather went about modeling the phenomena differently. He tacitly admits in the beginning of the paper his rejection of Clausius's equipartition theorem of 1857 and Boltzmann's ellipsoid molecular model of 1875, although he never mentions either men or their ideas by name.

The equipartition theorem explained that the properties of a gas could not solely be explained on the translational motion of its molecules. In other words, to characterize a gas as a set of moving billiard balls was an oversimplified manner in which to couch the phenomena. One has to assume that the molecules had other 'degrees of freedom', that they had rotational and vibrational aspects as well. A molecule was not as 'hard' as a billiard ball but could 'absorb' some of the momentum that was imparted on it: $K/H = 3/2 \times (y - 1)$ or more simply, $y = (n + 2)/n$ where n equals the degrees of freedom.²²⁵ Yet because discrepancies between theory and data still varied, Boltzmann had proposed an 'ellipsoid' molecular model with 5 degrees of freedom. In other words, collisions would not affect the rotational axis, which could hence be considered at unity (n would equal 1 instead of 2). The theoretical results were thus made to match more closely to experimental data: $1 \frac{2}{3}$ instead of the $1 \frac{1}{3}$ previously obtained.

In sharp contrast, Lachaud decided to implicitly reject all such 'ad-hoc' explanations as Boltzmann's and go back to the previous thermodynamic model that had initially provided so many new insights to the chemical community. “La forma elipsoidal no concuerda con ninguna de las propiedades de las moléculas y

no es admitida por ningun quimico...Admitiremos...que la energia representada por los movimientos secundarios de la molecula, es debil”²²⁶ Yet, in doing so, he was ironically going back to the ‘primitive’ form of thermodynamics as espoused by Adolf Kröning in 1856. Lachaud’s work also closely resembles that of James Joule of an earlier period, 1848. Joule calculated the velocity of hydrogen molecules at 60° from its specific heat. Using a model of 3 colliding molecules, he calculated that these traveled at 6225 feet per second, given in part by the formula $\sqrt{(\text{pressure per side}/\text{total pressure})}$.²²⁷

Why would Lachaud return to its more primitive form? Was Lachaud merely an incompetent physicist who did not know what he was doing? It does not seem to be the case.

His reaction could be accounted for in a number of ways. It was a very typical conservative French response to a very atypical intellectual crisis—when in doubt, return to the foundations. The French Revolution, which sought to eliminate all previous institutional sources of social order such as the Catholic Church, seems to have engendered a conservative spirit to its culture. Lachaud and Comte are but one of countless examples. We might also say that the response would have been typical of a chemist. Kinetic theory had recently revolutionized chemistry in what is now called physical chemistry. Although many chemists like Ostwald did not believe in the entities, it was giving a far greater degree of accuracy and prediction in the field. Ostwald, oddly, only came to recognize an atomic ‘billiard-ball’ model rather late (1909) although it had fruitfully served as the physical model underlying research. These intellectual dynamics in the chemical community are somewhat ironic given that at the same time, the ‘hard atom’ was obviously losing its validity in the physics community.²²⁸ We might also account for Lachaud’s reaction irrespective of any social constructivist explanandum.

A number of leading physicists of the day such as Max Planck and Lord Kelvin (William Thomson) had also expressed deep reservations with the equipartition theorem. In Kelvin’s famous lecture, “19th-Century Clouds Over the Dynamical Theory of Heat and Light”, the problem was the prominent topic. As shown by spectroscopy, the degrees of freedom within a molecule seemed to be infinitely larger than the ones that could be hypothesized. Planck, who had expressed his own reservations as early as the 1880’s, purposefully avoided any allusions to the equipartition theorem while developing the ‘quanta’. Yet the explicit reason that Lachaud claimed led him to reject this theorem was mainly based on philosophical principle: that of simplicity and beauty in science. Our models, he seems to assume, should not be so complicated that we don’t understand them, it defeats

their basic purpose. Our formulas should strive towards the maximum amount of beauty—a principle well espoused by Einstein and many other leading physicists.²²⁹ “Parece mas racional suponer que las moleculas tienen una forma tanto mas simple, cuanto menor es su peso molecular; y en este caso se tendra una concordancia que disminuira mas y mas, a medida que la molecula se complique.” It was impossible to imagine any other shape for the atom.²³⁰

Faced with such an anomaly, the range of reactions to the problem varied greatly, as reflected by Lachaud. One could, like Planck, reject the problem altogether and try to begin on a different basis. However, as Planck admitted, this was like stepping into the unknown—to him it was merely another ad-hoc response whose difficulties would eventually be resolved. As long as a new substitute could not be found to replace the theorem by an individual scientist, the likely tendency would have been to resort back to its original foundations. This is exactly what Lachaud did. Unable, or perhaps psychologically unwilling to leap into new ground, Lachaud tried to defend the initial posts that had given the field so much ‘security’. Yet there could be no middle ground physicists could stand on, as Planck’s own theory suggested regarding the behavior of light; there was no continuous range. They either ‘stepped up’ or ‘stepped down’ from their respective positions. Those who did not accept the new theory were forced to build up the foundations of the older theory hoping to resolve its weaknesses. Lachaud’s calculations essentially denied that such weaknesses existed by ‘hiding’ the obvious discrepancy in its model. Yet it was only by accepting this discrepancy that scientists would be forced on to new territory. One thus also had to accept the disparity (anomaly) before moving onto new research ground; Lachaud’s denial of the facts at the same time prevented him from moving further along. Given the intellectual dynamics, one could not stand with one’s feet in both because of their incommensurability. It simply made no sense, but these ‘zero-sum’ dynamics were to the general benefit of science.

We might also observe that Lachaud suffered the same deficiencies that Obrecht had as colonial scientists. The problem of specific heats was actually solved by Einstein by 1906. This work was expanded soon thereafter by Nernst and Lindemann, and then by Debye, Born and von Karman. According to Louis de Broglie, a participant of the quantum revolution, by 1913 the problem had been resolved for diatomic gases. Like Obrecht’s work, Lachaud’s was ‘obsolete’ before it was ever published, but less so.²³¹



It should not surprise us that the diffusion of modern physics to Chile after the 1PASC did not quite succeed. This was as much due to the recipient as well as to the provider and the inevitable differences between them. Although the full range of causes as to why the 1PASC and the North American entry did not succeed in diffusing science will be treated in another chapter, some obvious causes will be pointed out.

The state of Chilean physics at the time was in a relatively backward state when compared to that of Europe or even North America. The first surprising aspect is that so few of the delegates who discussed physics topics were actually physicists *per se*. Ducci was a physician, Lachaud a chemist, Leland a high school teacher, and Obrecht more of a cartographer. The professionalization of the discipline had not yet become a reality as it had in the United States, and the work duties of such potential scientists intruded into their intellectual interests. If the two endeavors were mutually beneficial, it leaned more towards the side of practical outcome than theoretical discovery.

However, we may also observe that the ‘failure’ cannot necessarily be attributed to a lack of expertise, of intellectual skills, or training *per se*. The ‘upper peaks’ of Chilean physicists reflected a relatively high level of mathematical sophistication and physical intuition, regardless of the fact that these had been directly imported from Europe. Many of the prerequisite skills were there, even if these still did not flourish. Their weakness seems to have been more due in part to that characteristic ignorance so typical of the colonial scientist. In other words, an ignorance either of the most recent research as in Lachaud’s case, or of complicated theories already well established as in the case of Obrecht. Knowledge of the latest research is essential if an individual’s scientific work is to be of any original merit. The same observation, however, obviously cannot be made of their German counterparts in the twentieth century.

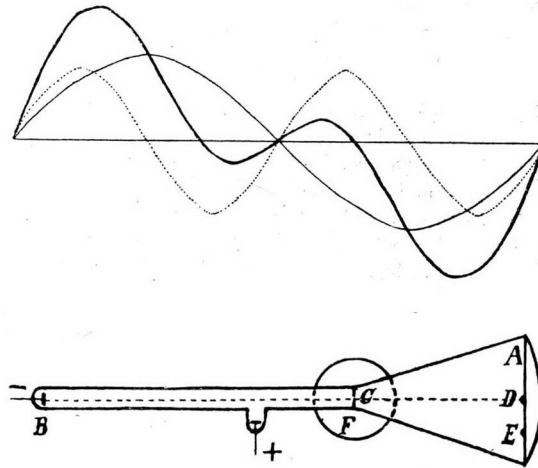


Figure 18: German 'Wehnelt' cathode ray tube and sound waves²³²

One should note that Chileans did not necessarily need to rely entirely on the U.S., nor had they until 1908. A number of articles in the University of Chile's *Anales* had been published which pertained to recent advances in modern physics, mainly by German émigrés. Certainly, they were not highly mathematical but rather described experimental advances; Roentgen's x-rays were prominent among these prior to and even long after the 1PASC. Curiously, this emphasis on the empirical as opposed to the theoretical was also characteristic of the science in the U.S. as well. Such a deficiency, however, should not be considered unusual in that the Chilean journal also published mathematical papers. The small number of mathematics articles seems to have generally increased with time, with sporadic treatments given by native Chilean authors. These efforts, however, did not fully succeed in altering the intellectual culture of the region.²³³

Yet, it was not only that the 'latest physics' did not diffuse, but also that physics as a whole did not either. The history of physics in Chile until W.W.II is characterized by its lack of presence. If organized research in physics began in the U.S. around 1875, it would not begin in Chile until around 1953. That relatively few Chileans spoke the language of mathematics acted as a barrier between the two cultures.²³⁴

A science department had long existed but most who taught there were rewarded for their ties to industry than for their scientific research. They were mainly engineers who dedicated only a relatively small percentage of their time to

science, and primarily then in the form of teaching. While certainly the ties between industry and science do not in and of themselves necessarily inhibit original scientific research, as in the U.S. or Germany from 1900 to 1945, its negative influence clearly manifested itself in Chilean physics at the turn of the century. These ties, as in the case of Obrecht's canal study, did not encourage basic research but rather tended to promote the repetition of well-established methods for the solution to practical problems. So predominant was this orientation, that in 1927, Carlos Charlin of the University of Chile criticized the overly pragmatic emphasis, stating that, "la Universidad debe ser algo mas que una gran Escuela Profesional." Augusto Knudsen, an engineer and professor at the University of Chile, is perhaps a classic case of this trend. His brilliant presentation at the IPASC was a summary exposition of thermodynamic mathematics. Yet not only were there no new and original ideas, but it presented these ideas strictly in terms of Newton's laws of gravity. At such a rate, science would progress only at a minute fraction relative to other nations. A certain 'scientific entrepreneurial spirit'—a 'je ne sais quoi' as some Mexican academic elites like to say—was missing. This seems to have been a pattern common throughout much of Latin America.²³⁵ It simply lacked a scientific culture.

These were not the only problems however. Financing was also an issue that could more directly be addressed. By 1953, Rector Juan Gomez Millas began instituting real changes with visible results in the local infrastructure by setting aside funds for the creation of laboratories with relevant instruments for serious research. Yet the cultural difficulty local scientists faced in expanding their proportionate share of resources is further clarified when one considers that when these reforms were implemented, it was complained that scientific journals were not needed as nobody would read them.²³⁶ If such were the obstacles of scientific development while it was receiving direct U.S. and UNESCO stimulus, imagine the difficulty that must have existed around 1908. Although in 1928 an "Instituto de Fisica y Matematicas" was created, it simply did not have the means to make world-leading research in physics a viable possibility, financially or spiritually. The conditions at the turn of the century must have been no better.

However, we should not 'blame' Chile or the Chilean scientists. We cannot be condemnatory for factors that were the result of history and beyond their immediate control. As Elihu Root once observed of Cuba, to expect any rapid change in a nation's general outlook is highly unrealistic.²³⁷ It is like asking a German to acquire refined French peculiarities, or a Britton to take on Spanish sleeping habits; it simply does not happen. Cultural traits have a persistent durability, and remain present long after those factors that had initially created them have disap-

peared. It is clear that the non-entrepreneurial ethos engendered by the parasitic Spanish rule during the Colonial period had also infested the Latin American scientific mentality as well.²³⁸ One should notice, however, that the same dynamics influencing cultural change were also affecting scientific development—a point that is all too often overlooked by historians of science.

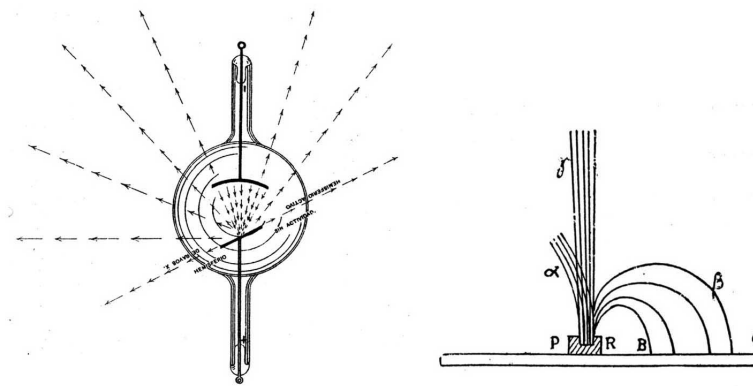


Figure 19: German x-ray instrument and deflection of beta rays²³⁹

We might also point out that the possible cause of German cultural reclusion can be accounted for in scientific terms. Fully assimilating themselves into the local culture might have degraded the quality of their scientific mentality, thus encouraged them to keep their distance—at the pace German science was then moving, they had a great deal to lose. It was not the only factor.²⁴⁰ With regard to French science, since throughout the second half of the nineteenth century it had been declining, there was less of an incentive to preserve its scientific traits and hence to isolate itself from the surrounding society. Application of its conclusions would lend this group influence, even if it certainly did not increase the total sum knowledge of basic science. In other words, the French could profitably draw on their past scientific earnings without making any further significant investments into the contemporary intellectual infrastructure—an important counter-observation underlying the principles of Vannevar Bush's scientific policy.

Again, it should not surprise us that Chileans did not participate in the quantum revolution. Nor should it be taken as a personal insult—it is merely a statement of fact. Regardless of the particular causes for Chile's lack of participation in the quantum revolution, its case was the historical norm rather than the aber-

ration.²⁴¹ Very few nations in the world ever were members of the “quantum generation”—a small elite who seemed to have been forging their own unique culture.²⁴² Although most participating nations (individuals) had been European, it was only a very small fraction of the total that contributed any advances. France had generally lost her theoretical preeminence by the late nineteenth century. Italy did not participate either, in part because it was focused on other scientific problems. Spain, like Chile, had only recently begun to support and develop her institutions in physics; it was afflicted by the same past that undermined Latin American science.²⁴³ European colonies such as Australia, while making many contributions in terms of individuals, themselves remained relatively backwards. Given the resources at the British metropolis, an early brain drain was seen to flow away from the periphery thus denying it of important human scientific capital.²⁴⁴ If this was the case of Western nations, imagine that of non-Western nations like India or China that so greatly differed culturally, linguistically, and economically. It seems nearly miraculous that Japan advanced as quickly as she did.²⁴⁵

We may conclude by stating that the size of science in Latin America as revealed by the case of Chile was relatively small in comparison to North America. The *longue duree* of history manifested itself in cultural trends that were inimical to its growth—but it was a strong beginning given these circumstances. There were economic factors orienting local intellectual interests towards areas outside of physics. We already have gotten a brief glimpse of these in this chapter. It is towards such dynamics, the interplay between an existing economic stimulus and scientific growth, which we will turn to next. If Japan’s economy helped drive its physics, Chile’s economy drove its chemistry and cartography. These two fields were to become the leading sectors of Chile’s ‘scientific economy’ at the turn of the century. An analysis of these dynamics will further elucidate the broader processes that have affected the scientific development of Latin America.

4

Nitrogenous Alchemy:



The Economic Foundations of American Chemistry

“Chile esta en el buen camino del progreso, pero naturalmente no es posible hacer todas las cosas de una vez.”

—Federico Ristenpart.

On March 23, 1908 there was an explosion at Chile’s munitions warehouse in Batuco so powerful that only a one hundred fifty foot crater sixty feet deep and a few, barely-discernible, ten centimeter pieces were all that was left behind. The warehouse had been filled with 130 tons of munitions in the form of nitroglycerine and black powder. Although pale by modern comparisons, the explosion and its effects are no less dramatic in relation to human size; it also must have been heard for miles around. Fortunately, despite the material losses, nobody was killed in the incident.²⁴⁶

Possible causes are perhaps not too hard to fathom. A modern insurance claims adjuster might have pointed to the fact that since the warehouse was located twenty-eight kilometers from Santiago in the middle of the desert, heat must have played a role in the explosion. The temperature that day had risen to 47.50 °C (117.5 °F) and the doors had not been opened for more than a week. He would, not all too unreasonably, speculate that such extreme conditions must have acted to create an oven inside the warehouses, cooking the ingredients to combustion. The weather was the ‘smoking gun’ that pointed to the culprit. It was also well known that previous explosions had been due to chemical reactions formed when the two ingredients were mixed together. The insurance claims adjuster would have attributed cause to human folly for the incorrect placement

of either the warehouse and/or its ingredients in close proximity and then have likely withheld his company's services, much to the chagrin of his clientele.

A military official, on the other hand, might have speculated arson. Chile had a long list of conflicts with its neighbors, Peru and Bolivia, over northern boundary regions. Although the War of the Pacific had ended in 1883, both Peru and Bolivia had been the clear losers of the vast fields of nitrate from which all explosives prior to W.W.I had been made. By the turn of the century, these nitrate fields provided more than half of the Chilean government's income; almost a century later, Salvador Allende still referred to the region as providing the "salary of Chile".²⁴⁷ The issue of ownership would not be fully settled until 1929, and so in 1908 there was still much resentment over this loss. Any one of these two countries, or both given that they had formed secret alliances before the war which had started in 1879, had ample motive to alter the regional balance of power which now favored Chile.

Disagreeing over the role played by reactions, the military officer would have pointed out that although ten tons of black powder had been recently deposited beside the nitroglycerine, the previous supplies of black powder that were thirteen years old had shown no signs of decomposition. He would also have noted that the maximum temperature had been reached at around two in the afternoon, not at 5:55 PM when the explosion occurred. By then, the sun had already started to set behind the mountains and the air had already significantly cooled. The smoking gun pointed elsewhere.

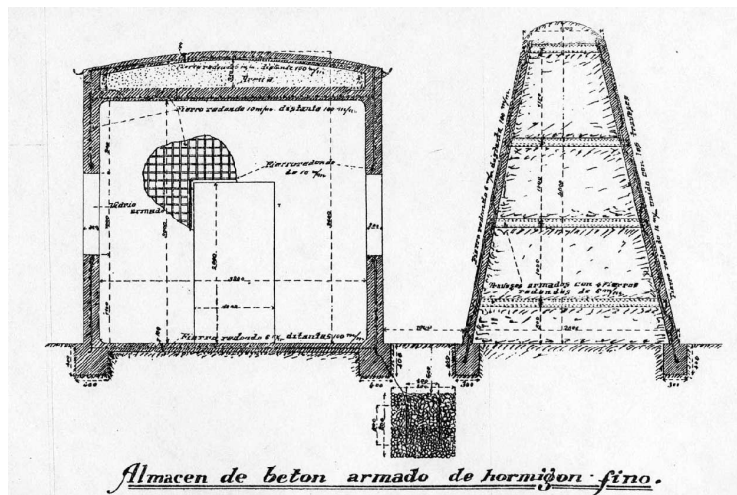


Figure 20: Design of warehouses

Despite these 'obvious' facts, both guesses would have been wrong. Only science, not common sense, could have led to the explosion's true cause.

Because the evidence was so conflicting, the puzzled Chilean government put two engineers at work to study the case: Manuel A. Delano and Roberto Oehlmann. Although both were under the employ of the military, they had strong scientific credentials. Delano, a lieutenant colonel, was a member of the Chemistry Society of Paris while Oehlmann had been a recently hired German professor at the "Escuela de electricistas". Their study, which was presented at the IPASC, showed that although the weather had indeed played a role in the explosion, it was of a much different kind than what most would have expected.²⁴⁸

Delano and Oehlman found an answer in the evidence above: the explosion was due to the creation of a strong electric potential in the warehouse which likely created a spark in the black powder, propagating itself directly via the smokeless nitroglycerine. Given the effect of the powder, the nitroglycerine likely did not combust but rather exploded instantaneously, thus greatly increasing the power of the explosion. The spark had not come from an electrical storm, as none had been seen that day, but rather from the sum total of the components involved. In other words, a self-exploding battery had been formed of the warehouse.

The weather had indeed been the key agent. It was not the heat per se, but rather the heat differential that encouraged the charge formation. The Chilean desert changed temperatures radically, and had been known to go down to as low as 8.8°C (47.84°F). This rapid change over a large temperature range greatly increased the electric potential formed. The dry weather also encouraged the spark formation because a lack of water in the soil made it a poor conductor, thus again encouraging the formation of a charge differential between the soil and the air rather than dissipating the charge throughout the ground. The metallic vessels in which the powder was contained also helped to create a sort of leyden jar, a battery, by interacting with the galvanized plates used for the roof. The dust that was found in the black powder helped close the circle because it was mainly carbon, which is a good conductor of electricity. These conditions meant that a charge was as easily created as it was propagated throughout the material, consequently leading to an explosion occurring at a time when it was least expected. The accidental explosion had not been clandestinely planned by Peru or Bolivia but rather had been 'an act of God', as it is now ironically termed. Delano and Oehlmann in their special report had solved the mystery. Chemical knowledge regarding the behavior of matter, not common sense, had saved the day.

The incident is but one historical example of how useful science could be. We may well imagine that without such knowledge Chile could easily have turned to blaming its neighbors and thereby acted to foster inimical relations between them. Common sense would have led to common war. Without being naive, we may claim that science helped prevent and resolve international disputes as the above case illustrates—even when it was also used to exacerbate these in the development of new weapons such as nitroglycerine. In either case, however, this use of science was more akin to technology in that it was used to the direct practical benefit of the state and the society it embodied.

Almost all of the presentations in the 1PASC volume pertaining to chemistry had some sort of direct application.²⁴⁹ As such, it provides a clue as to the dynamics of scientific development in the region. Chile, as the world's leading exporter of nitrates, was stimulated into electrochemical researches. Argentina, stimulated by its prominent beef industry at the turn of the century, was heavily involved in rather sophisticated colloidal chemistry. In other words, all nations that made presentations in chemistry, dominated by the two countries, did so with respect to their predominant economic interests. We may similarly frame Alberto Obrecht's work previously discussed in this context.

When one views Chilean maps of the time, it becomes very clear that those areas which had been most actively triangulated were those which were of prominent economic interest: the Atacama desert where the nitrate fields resided, the region surrounding the capital where its agricultural lands lay, and the southern region bordering Argentina which was also of significant agricultural value. The areas in between are scarcely triangulated.

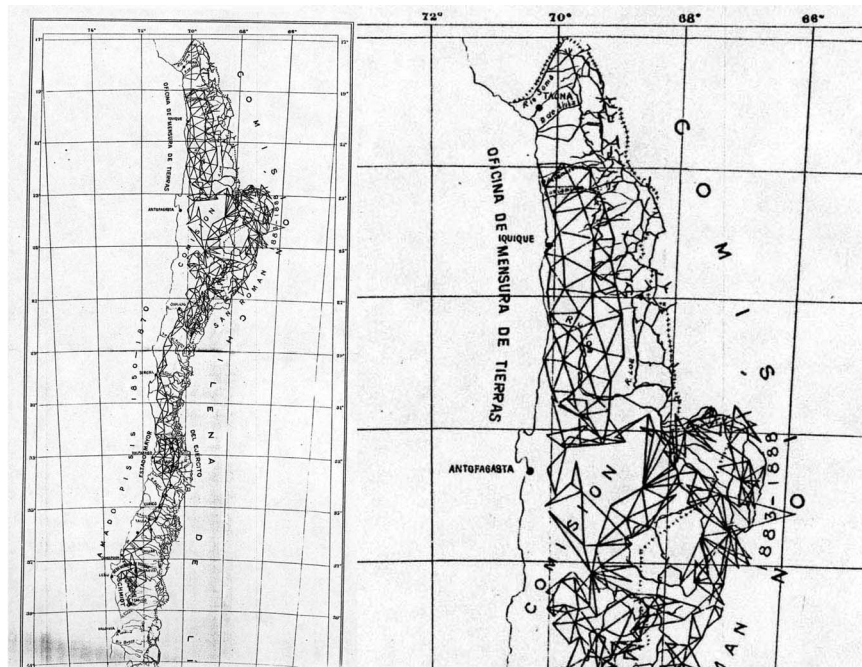


Figure 21: Triangulation of Chile and enlargement (Riso Patron)

His vast number of cartographic works helped insure that disputes over ownership of valuable nitrate lands would not emerge over the most trivial of reasons—new foliage, shifted land markers, etc. Although after independence Latin American nations had agreed on territorial partition based on the principle of *uti possidetis de jure*, the Spanish had not accurately established a reliable cartographic system, and land ownership was thus still open to much dispute. For example, although the Copiapo or Salado Rivers defined Bolivia's border, these often dry rivers made it difficult to locate their actual course.²⁵⁰ Only by using a relatively unchanging framework in the stars as Obrecht had, could reliable locations be finally established. A science as far removed from Earth's daily events could be practically applied to man's benefit. As a result, its support by the state enabled the concurrent development of its more non-applicable philosophical aspects discussed in the previous chapter.²⁵¹

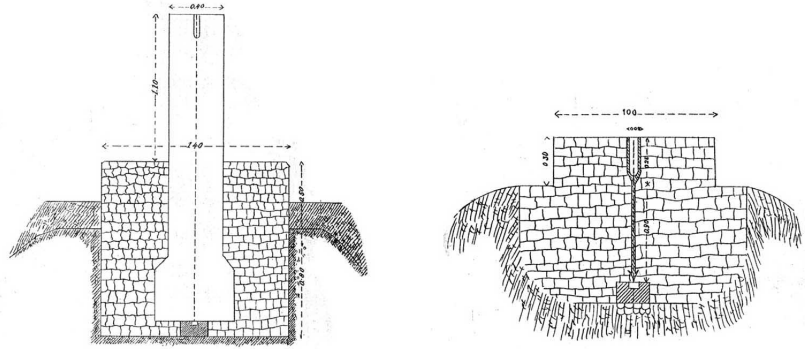


Figure 22: Mounds used for triangulation (Riso Patron)

These ties between the economy and science meant that those sciences which were most directly beneficial to existing industries were the ones which received the greatest state sponsorship, and hence the ones which were most proactively developed. (Little science can show the same dynamics as big science under certain social conditions.) As such, it provided a social stimulus that was altogether independent from its intellectual dynamics. This is significant because if Latin American countries previously lacked an internal-intellectual stimulus, they were encouraged to scientific development when the economic means became available, as will be shown in the case of Chile and Argentina. The economy thus not only provided the funds that allowed the science to progress, but it also affected the content of that scientific research.

Because the influence on physics is somewhat more removed from the economy, such relations are more difficult to trace than in the case of chemistry where it is much more direct. While the history of the former can thus more easily include philosophical and quasi-religious factors, one seldom sees these within the history of the latter but rather mainly those of economics. Oddly, however, despite the many studies pertaining to the subject, most deal with the influence of science on the economy rather than the influence of the economy on science. Barkan's study of Walter Nernst is an exception in that she shows how Nernst's commercial interests influenced the development of his third law of thermodynamics.²⁵² It is to this last set of dynamics, the impetus that a regional economy gives its science, with which the chapter will mainly deal.



Caliche, salitre, NaNO_3 or sodium nitrate, however one wants to call it, was Chilean gold. Although Chile had not participated in the gold-silver rush that occurred in Mexico and Peru during the Spanish colonial period, the discovery of this nitrogen-rich mineral resource propelled her onto the world stage.²⁵³ Ironically, it also encouraged the same kind of industrial stagnation that had previously beset her neighbors—wealth would be defined as the exportation of natural resources rather than value-added finished goods. Yet it enabled Chile to ride an increasing wave of prosperity which had initially been created by copper exports in the 1870's.²⁵⁴ Thus, unlike Peru, the Chilean economy in the last half of the nineteenth century had been able to stay relatively afloat. As average yearly production of sodium nitrate increased from 500,000 tons in 1882 to 2.7M tons in 1913, Chile's share of the world nitrate market expanded from 26% in early 1880's to 78% by 1905. Chile's net income from the proceeds would increase from \$ 0.8 M (U.S.) to 29.3M by 1910; the share of the industry to national income increased from 4.7% in 1880 to 51.32% by 1910. The First World War would eventually cut off this market, and encourage Germany, who had imported a great amount of this product, to develop an artificial means to the same ends.²⁵⁵

Somewhat ironically, Chile was not initially interested in occupying the Tacna-Arica region where the nitrates lay. Perhaps this was because value was placed in guano and the islands that held these, by then a declining industry.²⁵⁶ Peru had had a monopoly on guano production that, like nitrates, is also used as an important fertilizer. She had even offered some nitrate-rich territorial concessions that Chile had declined. Nonetheless, they still went to war.

The causes of the War of the Pacific, which had been fought over these lands, seem to have been relatively trivial. Bolivia's decision to increase taxes by ten percent on the region in which local Chileans had an industry and were the prominent population in seems to have sparked the conflict. A treaty between Bolivia and Peru also forced Peru into the foray as had occurred in Europe during W.W.I., but Bolivia's negligible forces meant that the conflict would be one mainly between the other two countries which stood at roughly the same level of military preparedness. The takeover of Lima by Chilean military ultimately proved decisive in the conflict; Chile extracted as much as she could from her rival's defeat. Aside from her nitrate sources, Peru would loose some guano lands as well, while Bolivia her corridor to the Pacific. Not fully resolved until 1929,

Chile's northern boundary was extended from latitude 25° south to 18° . Although myths of the war abound to this day in the national consciousness, in global terms, it was a relatively small and localized conflict that did not bring in other Latin American nations partly as a result of U.S. diplomacy.²⁵⁷

The war had ironically been fought over a substance that is as common as air. In fact, it is air. Nitrogen makes up almost 80% of the earth's atmosphere. Yet nitrogen, as the phosphorus found in guano (dried bird droppings), is an essential ingredient needed for plant growth; it helps form amino acids necessary to plant structure. As might have been noted by its chemical equation, sodium nitrate has relatively high amounts of nitrogen, about 20%, which in its powdered form can easily be directly applied as a fertilizer. The differences in plant growth when it is present are quite drastic. Maize crops will only yield is 600 kg/acre without it, but when eighty pounds are applied, the yield rises to 5040 kg/acre. With 280 pounds, it exponentially rises to 8820 kg/acre. Relatively small sums thus give rise to a much greater tonnage of plant production; in other words, with its use there is significantly more output than there is input into the system.²⁵⁸

Yet because nitrogen with its strong double bond is such a stable element, its natural fixation in the soil comes about only as a result of great energy input, in particular electric lighting. So long as human populations were not relatively large, it was not a problem. Agriculture could be continued at minor levels thereby allowing the soil to be naturally replenished in this manner. Purposeful human efforts such as crop rotation, disuse, or brush burning could also provide some needed nutrients. However, with the industrial revolution and the significant increases in population, demands for food and consequent agriculture outpaced the natural rate of nitrogen soil fixation.²⁵⁹ The discovery of sodium nitrate as a fertilizer helped keep the growth of agricultural production apace with human population growth; one might say that it literally amounted to an early green revolution during the second half of the nineteenth century. Yet so quickly did the demand exponentially rise, that by the time of the Spanish American War Sir William Crookes of England had already warned that population growth would soon outrun supplies early in the next century. However vast the nitrate fields in Chile were, they would eventually run out as the Peruvian guano islands had—leaving not only the nation in financial straits, but also humanity in worse conditions than that from which it had initially started. In the meantime, however, those with the resource stood on fields of gold.²⁶⁰

Sodium nitrate was also a product in high demand because it was used in the growing explosives industry. Mixing sulfur, charcoal, and sodium nitrate produces black powder, for example. All explosives prior to W.W.I used some form

of sodium nitrate. During war, when 'nitrogen reserves' were low, nations like Germany were forced to choose between its two uses; food was not necessarily always a top priority. Because of its multiple uses and lack of viable rivals, the Atacama desert's nitrate fields had been a highly valued mineral commodity around the turn of the century.

The demand for its many uses simply meant that those nations with 'proven reserves' of the material stood to gain a great deal of wealth by its export in the world market. Exponential human growth and continued military conflicts guaranteed a ready demand, and in turn, profit. Chile was not the only one to go to war for such territories. These discoveries had also stimulated the exploration of many islands throughout the world by many nations, including the U.S., which eventually took over 94 islands worldwide, an act which was justified with the Guano Islands legislation of 1856. Curiously, Chile took a very different stance to its nitrate development than Peru had in the case of guano—allowing the private development by the British. These in turn were able to take over the local industry by a bit of luck and perseverance. The value of titles to these lands was insecure given the unknown outcome of the war, and with its depressed prices, people like John W. North bought a great many titles, whose value greatly increased at the end of the war and Chile's recognition of these private titles.²⁶¹

Given the prominent role that sodium nitrate played in the world market and hence the Chilean economy, it is perhaps to be expected that Chilean chemists at the IPASC would consequently make presentations in the topic. Of the 8 Chilean papers in the volume, only one was not related in any way to the nitrate industry. Even one by Carl Malsch, which addressed mainly legal issues, touched on the means of testing the concentration of nitrate in soil samples. Malsch was a chemistry professor at the school of Engineering. The most prominent Chilean author was also the editor of the volume: Belisario Diaz Ossa, a professor at the University of Chile.²⁶²

In what were rather typical scientific apparatus of the time, Diaz Ossa described how he tried to produce nitric acid by means of electrolysis.²⁶³ Diaz Ossa used a 'disolucion acuosa' of sodium nitrate, 85.09 mol. grams/liter, a porcelain diaphragm, and a current of 2.5 amperes. However, instead of getting an improved current with the production of ions in the solution, the actual resistance increased with time. He also found that the amount of hydrogen retrieved was much lower than that which theoretically should have been produced. When a capillary tube was placed horizontally around the porcelain diaphragm, pinched by tweezers at each end, and the resistance again had greatly increased after a new

application of electricity, the removed tube was found to have been completely filled with water.

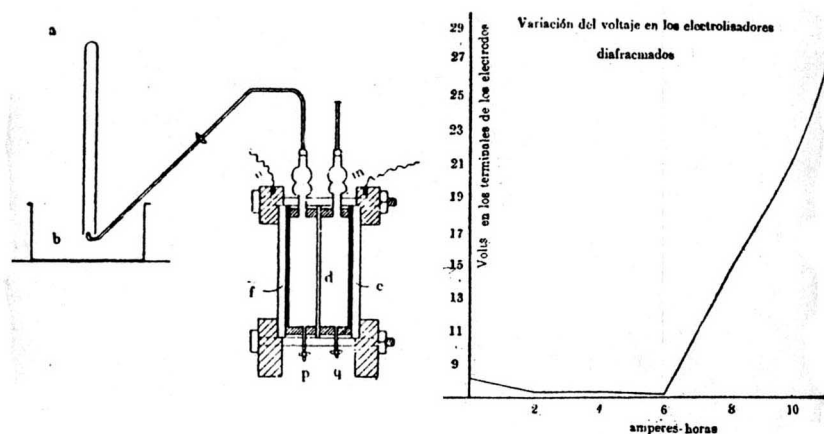


Figure 23: Dias Ossa's instruments and resistance curve
(Note the decreasing resistance, prior to the exponential rise.)

A thorough analysis of chemical equations revealed that the H and OH ions that were passing by the diaphragm were interacting with each other to produce water. Instead of $\text{Na} + \text{H}_2\text{O} = \text{Na}(\text{HO}) + \text{H}$, where $2\text{NO}_3 + \text{H}_2\text{O} = 2\text{HNO}_3 + \text{O}$ resulted as a secondary reaction, the one obtained had been $\text{NaNO}_3 + \text{H}_2 = \text{NaNO}_2 + \text{H}_2\text{O}$. A second set of experiments showed that when a dripping mercury cathode was used, it combined with the hydrogen ions, and thus prevented these from combining with OH, thus leading to a more successful experiment.²⁶⁴

It should not escape our attention that the author was trying to chemically produce “nitrogen” (sodium nitrate) by electrolysis—which unfortunately eluded his efforts. Nature would not be tamed so effortlessly, as Fritz Haber’s work in Germany showed.

In his second article, Diaz Ossa described improvements in the nitrate industry.²⁶⁵ It is a professional’s view of the sometime ineffective procedures of the industry. He explained that salitre was obtained from the caliche layer of soil by dissolving it in hot water, a process known in Chile as “lexiviación”. A number of secondary products, chloride (cloruro) and sodium sulfate were also dissolved, but as long as these did not reach above 5% of solution, it did not affect its commercial value. (The next experiment dealt with the issue.)

However, Diaz Ossa warned that miners were often heating the vats too much with little effect, wrongly believing they would get higher concentrations of the new gold. “Las disoluciones que tienden a saturarse, las mas concentradas sean, de manera que la cantidad de calor consumida en elevar la temperatura en una disolucion concentrada es mayor que la que consumiria una disolucion diluida, en las mismas condiciones”.²⁶⁶ In other words, the solutions with highest nitrate concentrations had the highest specific heat; the amount of heat needed to raise temperature one degree was much higher in higher concentrates relative to the poor solutions. This meant that changes in a solution’s specific heat could be used to gage when the solution had reached its nitrate saturation point. When much more energy was needed to raise its temperature, Diaz Ossa pointed out that the solution had reached its final peak state. Miners could rest assured that they need not spend more on wood or other fuel resources to obtain more pure salitre. According to him, the best processes (most economic) were those utilizing lower temperatures; the important differences really came mainly from the method of evaporation.²⁶⁷

Other problems in the industry were also discussed. Local businessmen, Diaz Ossa informs us, had created numerous mechanical contraptions to treat the substance. “Muchos han creido que solo era necesario efectuar modificaciones mecanicas, cambiar la formal de los cachuchos, o recipeintes y han adoptado la seccion exagonal, en vez de la cuadrangular usual; otros han ideado cachuchos rotativos adoptando formas muy variables.” Needless to say, these improvements affected the mechanical system but not the chemical reactions themselves.²⁶⁸

Perhaps the most strictly chemical presentation per se by the Chilean delegation was that by Pablo Moriozot and Juan Rochefort P, of the Universidad Catolica.²⁶⁹ It was unknown whether *sulfato* (sodium sulfate) negatively inhibited *lexiviacion*, and the two devised a test to see whether it actually did or not. Although not too chemically complicated, they were gaining basic data of nature. We may note that Diaz Ossa’s previous articles were mainly the application of previously known knowledge rather than discovery of new knowledge.

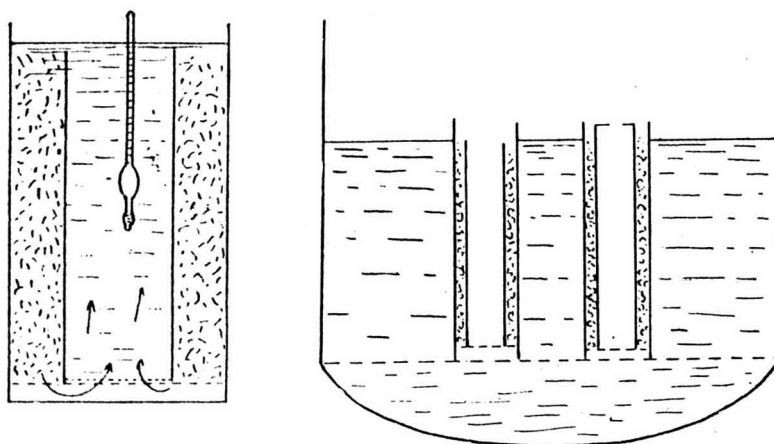


Figure 24: Moriozot and Rochefort's "sulfato" experiment

The experiment is relatively simple but carefully constructed. The basic aim is to compare the concentrations of two heated solutions, one with and the other without *sulfato*. They place a smaller cylinder with a wire mesh at bottom within a larger cylinder with a false bottom. This allowed the salt solution to enter the inner chamber, whose density after heating was to be read using Twaddell's "aerometro". Two pairs of these cylinders, one with a salt solution of sulfur and the other without sulfur, were placed in a very large "pot" of sorts, also with a fake bottom. The water filled pot is heated by gas, which then transfers the heat to the cylinders. Respective measurements are made at temperature intervals, where samples are taken to see if sulfur has an inhibitory effect on "la elaboracion de salitre." The actual amount of material is made to be equal: same amount of *salitre*. However, while one container had 400 grams of the salt, the other has 300, along with 100 of "sulfato de sodio" (sodium sulfate).

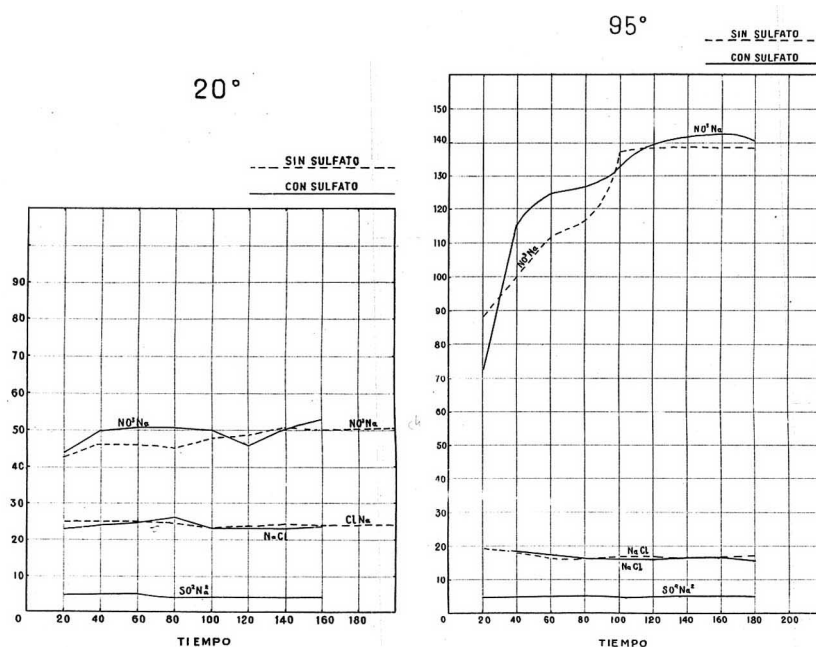


Figure 25: Moriozot and Rochefort's resultant figures

They were careful to get exact measurements—especially when at higher temperatures in which evaporation would have considerable effects, “sin esta precaucion habria sido imposible toda pesada exacta.”²⁷⁰ A sample was taken every 20 minutes, making sure that the interior of the cylinder was cleared so that the full amount of solution could enter it. (See diagram.) The amount of nitrate was determined by its reduction in presence of “sulfato ferroso”. They found that “sulfato”, contrary to common belief, had no effect whatsoever; “concluimos que la accion del sulfato es nula, lo que nos permite decir que el poco rendimiento de los caliches que lo contienen, no es debido a esta como se cree actualmente.” Irrespective of the varying temperatures, the density curvatures followed the same normal path with or without the presence of sulfuric salts.²⁷¹

As can be seen from the three above examples, Chile's main industry (sodium nitrate) was the principal focus of chemical concerns at the IPASC. Chilean chemists had found that sodium sulfate did not affect its processing, that water was formed when treated to electrolysis, and that increased heat would not alter the rate at which it was dissolved. What did and did not affect salitre was chemically analyzed, thus giving a more grounded knowledge of how the substance

interacted with, and was affected by, others. Its physical states were more appropriately understood. All of their experiments helped improve the efficiency of the local industry.

Yet the science used in these experiments, physical chemistry, had only recently developed in the 1880's, and such experiments attest to the rapid diffusion of this scientific discipline within the region. The main authors cited by Diaz Ossa had been Ostwald (1902), Hittorf, Nernst & Loeb (1888), and Noyes (1903). As noted by van't Hoff and Walter Nernst, such simple experiments using very dilute aqueous solutions found in the IPASC had been essential to progress in physical chemistry, a field which is of much more historical importance than has been accorded by historians of science which have traditionally favored physics. It is a poorly known fact that Max Planck prior to his quanta work had been more well known for research in physical chemistry—a historical fact which is “erased” by later outcomes. Curiously, when some nations in Africa tried to enter the modern chemical industry, they did so using the same inexpensive procedures.²⁷²

While the above relation between the Chilean nitrate industry and the development of its physical chemistry may not sound surprising, we may complicate the issue further and inquire as to why the economic stimulus of science did not proceed to industrialize the nation. If the engine of economic progress helped moved Chile toward greater scientific development, and this development is a crucial ingredient to further economic progress, then why did this process not also significantly take Chile on the path towards industrialization as it had in Germany?

Curiously, the answer seems to have more to do with a lack of will and the influence of culture, than with any potential technological or scientific obstacles. Simply put, it appears that Chile simply did not want to industrialize. There is no other way to put it. We need not, however, project our assumptions as to its *a priori* value onto our historical actors and judge it in a negative light.



In hindsight, but only in hindsight, Crookes need not have worried too much; the world was not going to run out of nitrogen.

Although W.W.I cut off Chile and its markets from each other, it also served a great stimulus for Germany to produce nitrogen on her own (and for Chile to industrialize). It either undertook its production or she faced a rather early and embarrassing defeat. Despite the fact that she did not have the same mineral

resources as Chile, Germany had a scientific might in organic chemistry which had itself also been spurred by the economy. The modern industrial research lab was really born there, under the auspices of dye companies seeking to extend their position in the market. Britain's early lead in Perkin's mauve dye had given way to the German behemoth which by the end of the century was producing hundreds of dyes, itself stimulated by a 1871 patent law whereby processes, not products, were subject to patent.²⁷³ This meant that as long as a company could produce the same dye by a different set of reactions, she would have legal access to such markets. Hence, the dye industry gave birth to the industrial research labs the likes of BASF, Bayer, Hoesch, and others—German firms which are still predominant to this day despite their repeated destruction in the century's two world wars. However much the Alliance for Progress tried to stimulate industrialization in Latin America, it did not create the necessary foundations of such industrialization as that which had “naturally” occurred in Germany: the creation of a competitive national scientific ethos.²⁷⁴

Although the physical chemistry used to devise a viable industrial nitrogen fixation process had been of Scandinavian origin, in being the first to discover the process Fritz Haber became a hero in Germany.²⁷⁵ A great number of physical chemists, including its founders Wilhelm Ostwald and Walter Nernst, at some point had also tackled the issue. Nernst gave up, on the advice of industrialists, thinking that it was then impossible. In all fairness, although Ostwald did not discover the exact manner in which to produce the substance, he laid the basic principles of such work. Some processes had been devised as early as 1902, but these arc or calcium cyanide methods took up so much electricity that they were simply not cost effective. Through patient and consistent hard work, the “self trained” Haber discovered its solution in 1908. Carl Bosch in BASF then devised the means to produce the same effects as Haber had in the laboratory, but at an industrial scale.

The simple equation to make ammonia, $N_2 + 3H_2 \rightleftharpoons 2NH_3 + \text{heat}$, was rather hard to put in practice simply because the temperatures and atmospheres needed for the exothermic reaction to take place were so high. If a fireman's water hose reaches pressures of 125 pounds per square inch, that needed for nitrogen fixation increases by almost a factor of ten. One observer noted that, “It is little wonder the gases finally combine if only out of sheer desperation.”²⁷⁶ Such pressures, however, were previously unheard of in chemical experiments or the chemical industry that preferred open batch processes like the ones Haber had first used to study the subject. The difficulty scientists of the era faced are further elucidated when we consider that even after German patents had been confiscated

after W.W. I, Germany retained a monopoly of the process because she had been awarded the right to keep information concerning its catalyst a secret. There had been 6,500 experiments performed on 2,500 potential catalysts only to find two: uranium and osmium.²⁷⁷ Using these extreme conditions and the catalyst, Haber had devised a means of “fixing” the common existence of nitrogen in the air to the pervasive hydrogen in coal (later natural gas) to produce ammonia. The intellectual and technological infrastructure needed for such industrial processes already existed in Germany, and provided the underlying foundation to Haber’s genius.

Thus W.W. I stands as a watershed of sorts. When Germany discovered its value-added product, ammonia, the world need no longer have been fully reliant on minerals for its supply of nitrates; it could rely on the readily abundant air. What had been good for Germany during the war would also appear to be good for the world during peacetime. An exponentially increasing world population would hence not be forced into a controlled growth partly because it had the fertilizers necessary to produce necessary agricultural foodstuffs. First spreading to Japan immediately after W.W.I, the technique and technology diffused throughout the world at a much faster rate after W.W.II. In 1958, for example, Japan produced only 16% of its national use, but by 1971 the figure had risen to 96%.²⁷⁸

Throughout the century the consumption of nitrogen fertilizer increased from 366 thousand tons in 1905 to 13,980 Th. tons in 1963. In that same year there were 263 synthetic ammonia plants and 42 under construction. The tables had turned and Europe became the world’s leading exporter of “nitrates” (ammonia) at 1,125 (Th. ton), followed by Japan at 555 (Th. ton); net importer countries included China at 400, India at 205, and Latin America at 170. Total European production lay at a staggering 5,195 Th. ton in the same year. By 1991, nitrogen had become the U.S. largest chemical product in sheer atomic mass at 26M tons of which 19M were in the form of ammonia. If sulfuric acid was once used as a leading economic indicator, ammonia clearly stands as a population index all by itself. The two show corresponding exponential growth rates.²⁷⁹

Could Chile have entered the production of nitrogen, and thus industrialization, at an earlier stage than she did and have maintained her lead in the more broadly defined “nitrogen industry”? If there was an economic stimulus from the development of her nitrate industry into her growth in chemistry, why wasn’t this stimulus further extended into the industrial process? After all, if synthetic ammonia stood as a rival to Chile’s natural *salitre*, it makes sense that Chile would have been stimulated to adopt this technique to thwart rivals within her

own economic realm. That she did not makes us inquire into the possible factors affecting the national decision-making process.

Chile followed the bandwagon and only entered the field towards the end of the 1960's, when all of the other Less Developed Countries (LDC's) were also rushing into the foray. Although Chile was indeed still exporting nitrogen in 1963, all of it was in the form of sodium nitrate; the total produced was 172 thousand tons with 34 thousand tons for local consumption. By contrast, Germany was producing 1, 269 Th. ton, of which 746 were being used for local consumption. Only in 1965 did Chile even begin a feasibility study on the project, and built its first synthetic ammonia plant at Punta Arenas with a capacity of 270,000 tons/year in 1971. This had been about twenty years after discovery of a crucial feedstock in the area: petroleum and natural gas. The late entry of Chile into the market simply made it much more difficult for the nation to find a competitive niche in it. There was a glut of nitrogen production during the late 1960's, which deflated prices despite the increasing capital costs of ever-larger production plants.²⁸⁰ Had Chile entered this market at an earlier period, as Japan had, she would have been in a much more favorable position than when she finally did enter. Again, because she had early ties to the market meant that she was poised to take much earlier advantage of the situation; we might now say that she had "insider" information of the industry.²⁸¹

The United States during the 1PASC warned Chile of these upcoming trends; instead of uttering the word "plastics" as in the well-known Dustin Hoffman movie, it mumbled the word "ammonia". It was the only country to have publicly done so during the congress. Curiously, despite the prominent British, French, and German economic and cultural influence in the region, it is surprising that we do not find these overtures by such nations anywhere in the 1PASC or in Chile's main scientific journal. One U.S. presentation gave the warnings, and another addressed the problem of the excessive national consumption of local resources.

Of the two presentations, "Carlos" Monroe's was perhaps the most direct.²⁸² A professor at George Washington University, he informs the local delegates of the new means which had been invented and were being developed to fix nitrogen—the synthesis of ammonia and the "calcio cianuro o nitrogeno de cal." "La amenaza de una extension del uso del nitrato de sodio en los Estados Unidos esta fundada...en la introduccion de procedimeintos electronicos en la fabricacion de nitratos sacada del nitrogeno atmosferico."²⁸³ He believed that it was likely that not all means were being reported in the media that had been discovered. For these and other reasons, the U.S. was proceeding to build its own plant at the

Niagara Falls, with the cheap hydroelectric power the damn constantly produced. He informs his audience that total U.S. production had increased from 196,059 to 279,790 tons by 1905, according to the most recent statistics, the larger half going to the production of explosives.

William Kent had also warned about the measures taken to limit consumption of national resources, in particular with the case of forests for charcoal.²⁸⁴ It was very difficult to do so because the individual usually saw only his self-interest defined in short term goals. However, because the state took aim toward long-term benefits, she had the right to infringe on what was perceived to be an individual's intrinsic rights. Otherwise, national resources would be quickly depleted and thereby undermine the general welfare of the entire nation.

The problems Kent discussed were highly akin to those that Chile had faced throughout the 1880's, ironically with the positions inverted between the state and private interests. Because Chile had become so dependent on nitrates, her pushes to continually increase output had caused conflict with British producers who were seeking to create a cartel in order to decrease production and boost prices. These conflicts of interest eventually resulted in a civil war of 1891 and the removal of Balmaceda from his presidency. Ironically, in seeking to build an industrial infrastructure with nitrate funds for Chile's long-term economic benefit, Balmaceda ultimately collided with the Liberal faction which saw such projects as mere examples of shortsighted nepotism and arbitrary decision-making, which in some cases they probably were.²⁸⁵ Although not directly addressed to Chile, the warning by the U.S. could not have been more applicable to Chilean national issues.

We may thus state that the lack of information transfer did not serve as an obstacle to Chilean industrial development. The nation had been publicly warned of the ammonia challenge as early as 1908. Studies of nitrogen fixation, like those of atomic physics, had also been rather prominent in the scientific media prior to the war. By 1915, there were already about 3,000 articles published in scientific journals.²⁸⁶ The "opening" of the German scientific establishment after its defeat in W.W.I, as would occur during W.W.II, also meant that many of these processes were brought into the international realm, even if not all aspects (e.g., the catalyst) were made public. When we consider that Chile did not initiate such a project until the 1960's, it is clear that a lack of information was not an obstacle to its development. This is particularly true in the case of nitrogen production, which, in contrast to chemical intermediates or finished products of the petrochemical industry, is relatively easier to import into a country—an issue that will be more fully analyzed later.

We may also note that “organic” producers seldom initiate a synthetic production that rivals their own. Usually more “natural” producers are overtaken by more “sophisticated” innovators. In this sense, the Rosenberg schema of technological innovation elucidates our case study. Rosenberg and others argued that when a technology is first introduced, it seldom takes over the market from one day to the next. Rather, there is a period of adjustment. The preceding producers try to introduce improvements into their product, which then enables their older product to more effectively compete with the new technology.²⁸⁷ When we consider that many of the IPASC articles generally sought to improve the efficiency of its salitre production, there are congruent patterns in that history with his general theme.

The question that then arises is whether Chilean chemists had been fully aware of changes in the early nitrogen fixation industry during the first decade of the century. Did they fully understand the importance of the information the U.S. delegates had provided? Were Chileans reacting to such changes in parallel industries (ammonia) or was their research merely a natural outcome of the desire to improve their own industry’s (sodium nitrate) efficiency?

Although U.S. presentations were directly pertinent to the Chilean national situation, these hints were placed under other topics whose prominence may have hidden its implied meaning. The focus of Monroe’s lecture was not nitrates per se but rather the validity of statistical methods used. Similarly, Kent’s presentation dealt mainly with slow-burning fuel resources; its relation to an agricultural resource may have not been that clear even if it was also used in explosives. It is thus not that obvious whether the hint was detected at all. It is clear that Diaz Ossa read German and French scientific journals, as did most other Latin American scientists of the time, and may likely have been aware of such research. However, we simply do not know whether he was aware of it, and if he was, if he understood its significance. That he did not seem to have undertaken research in the process might have been due either to his ignorance of it, or to the lack of existing capital.

Gleanings of the educational infrastructure help provide some clues to these questions.

When one surveys the leading scientific journal, the *Anales de la Universidad de Chile*, between 1898 and 1916, one finds that very few articles were published in chemistry, in sharp contrast to the prominence of biology, mathematics, and astronomy. Until 1905, only ten articles had been published which had anything to do with chemistry. Even these, however, are only indirectly tied to the field and could be more appropriately classified as pertaining to geology—a field more

in agreement with the more pervasive mining interests of the economy. There are no articles on nitrogen fixation, or even on the synthetic production of dyes. Only two articles published in 1888 were directly related to sodium nitrate, written by Julian Gustavo and Manuel A. Prieto, but even these define the issue “geologically.”²⁸⁸ Between 1908 and 1916, we do see more strictly chemical articles, but still very few: only three in total. Again, none of these use the Haber-Bosch process or synthetic dye processes. It is also somewhat odd in that Chile was still following the French with regard to chemistry, who were notoriously backward in this area.

It does not seem that the subtle warning had been clearly understood.²⁸⁹

We may also conclude from the low productivity of chemistry articles that one reason for the delay of Chile’s entry was due to the absence of a significant intellectual infrastructure such as that which was found in Germany during the first decade of the century. There were so many chemists in Germany, that the employment market had become glutted, thereby significantly reducing the prestige and income in the field. In 1907, there were about 5,800 chemists, which had grown from 3,000 in 1895. Most of these were employed in industry rather than academia, but many complained that it “no longer pays to become a chemist.” Johnson characterized the group as a proletarian labor force much like that which academia has become in our day. Yet, regardless of how detrimental this glut might have been to any one given worker, it was of great benefit to the industry as a whole. A skilled technical labor pool of the sort to make the necessary but routine-and-dull tasks essential for industrial research and development was readily at hand for a low price.²⁹⁰

This perhaps contrasts to the position of the chemist in Chilean society which was likely of a much more significant status simply because of the apparent undersupply relative to the existing demand. Because of the small size of the discipline, it is likely that the costs of his labor were much higher. The combination of both factors seems to have made it nearly impossible to establish the needed labor force sizes for industrial research laboratories.

The origins of “modern” chemistry in Chile are usually traced to the immigration of Ignacio Domeyko in 1838, who had been hired to teach mineralogy at the Instituto de Coquimbo, ultimately retiring in 1884 from a university post. Because the students generally lacked the requisite background in physics and chemistry, he was forced to teach these to the students. They were taught to distinguish between different metals, how to detect the quantity of mineral in rock formation, and other such useful skills. Chemistry seems to have received a great boost by the newly discovered Caracoles copper mine in 1870. A chemistry

department was formed inside the Instituto de Ingenieria, and was expanded in 1902 when the classroom size was expanded beyond the 20-student limit and new instruments as an electric oven were installed.

Yet during most of the nineteenth century, chemistry in Chile was a sub discipline that usually formed a subset of traditional disciplines like medicine, pharmacy, or engineering—a pattern that had been equally true in Germany until the mid-nineteenth century. As a result, there were very few chemists created; those interested in the area would have likely turned to those that more broadly encompassed it.

An 1895 survey of all non-humanist institutes showed that of the total 1,856 enrollments, there were only 189 students in chemistry-related areas, but these would more appropriately be termed as geological. The Laboratorio Quimico de Iquique, the only such laboratory included in the survey, only had 18 students. The survey's inclusion of fine arts and music, which had the largest enrollments, further underscore the figures.²⁹¹ The School of Medicine at the University tried to institute a formalized four-year pharmacy degree in 1886, but by 1897 they were forced to "eliminate" it for lack of knowledgeable professors.²⁹² Organic, analytical, and inorganic chemistry courses were part of its degree plan. Only in 1907 had a new professorship in the "explotacion de salitre been formed", and the he mathematics faculty at the University of Chile had also began to give courses for the *tecnicos de salitre*. In the year prior to the 1PASC there were a total of 166 alumni in the escuelas practicas de mineria of Copiapo, Serena and Santiago combined, schools that had recently been established in 1894. It would not be until mid century that a national Chilean society (1946), congress (1944), and disciplinary journal (1950) were formed.²⁹³

The "critical mass" needed for a viable chemical community was thus likely not formed until the end of W.W.II when the discipline obtained some of the large size and consequent needed cohesion. Chile's polytechnic schools during the first decades of the century simply could not compare to Germany's *technische Hochschulen*, which had even been granted the right to award doctorates by W.W.I and whose phrase had aptly been, "national wealth can be increased in no better way than by spreading...useful scientific knowledge." Even today, the number of chemists in Chile stands only at around 400.²⁹⁴

A comparison to the U.S. might place Chile's chemists in a better perspective. The United States, which obviously did enter the nitrogen fixation process, had so many chemists that the number of subdivisions within the broader umbrella organization was rather large. Although in 1900 there were only 5 subdivisions in the American Chemical Society, by W.W.II these had grown to 22. Between

1890 and 1915, 500 doctorates had been awarded in chemistry. More chemists, 468, are listed in a survey of the *American Men of Science* between 1906 and 1944 than the 138 astronomers, 257 botanists, 378 zoologists, and 377 physicists. Two chemical journals had already been formed in the 1870's, the *American Chemist* (1870), the *Journal of American Chemical Society* (1876). By 1893, 327 chemists had already published 1,186 articles.

Because of such numbers, firms like Dupont, as those in Germany, thus had ample pickings amongst the many chemists that were produced. Again, although it was of great benefit to the industry as a whole, it was of detriment to the individual worker, who was often given little credit for his originality. The relation between director Charles Reese and Arthur La Motte at Dupont is perhaps a case in point—something that is now standard across most industrial research laboratories.²⁹⁵

Yet Chile's problem, with respect to the labor force, seems to have been more chronic because it lay at a deeper level. It was not just that few chemists were produced by the higher educational system, but rather that the middle classes as a whole were a minute fraction within Chile's hierarchical class structure—a feature common to most Latin American countries. Even after "modernization", by 1880 most working individuals were still unskilled laborers, 85-90%, with a fraction of the remaining 10% belonging to the middle classes. In 1925, handicraft industries still made up 70.7% of the total industrial employment. Even by 1957, 50% of all industrial employment rested in 70,000 small business establishments. This means that not only was the skilled labor force needed to establish such industries miniscule, but also that consequently there were few companies that would have been able to purchase the production of chemical products. Certainly the central agricultural valley created an internal market for ammonia fertilizers, but other secondary tier industries, which also utilized nitrogen—based products, did not exist as the automobile industry had in the U.S. for its chemical counterpart. Although Chile's economy had become capitalist and oriented towards export, it was still affected by the legacy of Hispanic colonialism.²⁹⁶

This is not to say that the state did not try to create this educated middle class needed to support an industrial society. Perhaps one of the national tragedies in a Shakespearean sense was Balmaceda's failure to modernize the nation. He well knew that nitrate gold had to be invested into long term structures or otherwise it would be reduced to the same fate as Peru, who had wasted its guano income on the conspicuous consumption of European luxury items and railroads which often linked two nowhere points together.²⁹⁷ In 1886, of the total \$33M Chilean budget, \$10M went to public works and \$2M to education. In 1888 the figures

were \$40M, \$8M and \$6M respectively, in 1890, \$67M, \$21M, \$6M. School enrollment doubled from 79,000 students in 1886 to 150,000 in 1890. Consequently, the number of educational institutions quickly grew. Primary level schools rose from 881 in 1860 to 2,630 by 1905. Secondary educational institutions grew from 18 in 1860 to 167 by 1905; in higher Education, the numbers went from one in 1860 to 16 by 1905.²⁹⁸

Yet despite these efforts, 60% of the population was still illiterate in 1907. The percentage of the total population that became educated increased from 2.29% in 1879 only to 13% in 1895; one cannot help but note that these figures were incredibly low in contrast to Europe. It would not be until 1920 that primary education would be made universal for all students. Most of the pedagogical changes enacted around the turn of the century affected mainly the liceos rather than the universities themselves.²⁹⁹ We may conclude that while the general educational growth of the nation certainly helped provide a foundation for industrialization, it was obviously a long way off from fully building the skilled labor force needed to build, run, and make those creative changes needed in the chemical industry to remain competitive at an international level. The needed human capital, aside from its financial counterpart, was just not there.

It is interesting to note that only 8% of the Chilean population lived in the nitrate rich sector, which was a British-controlled enclave relatively independently of the surrounding society. Yet it was an enclave that, upon the development of the synthetic ammonia industry, gradually withdrew its funds from the region. The British were not stupid and could just as aptly spot a good deal as they could a bad one. British ownership rose to peak 60% in 1895, and declined thereafter to 38.5% in 1912 and 23% in 1925; inversely, Chilean ownership rose from 13% in 1895 to 68% by 1925.³⁰⁰ While this might be characterized as a joyous process of nationalization whereby the nation took increasing control over its assets, it really is not. Chileans were buying greater shares of an increasingly obsolescent product whose value exponentially declined with a vast increase in world output of its synthetic version. Chile's "salary" gradually came from a smaller and smaller pocket. They had purchased a lemon.

We may also point out that the nitrate industry is but one example of how poorly Chileans were in control of their national economy. Chemical related industries—tanning, brewing, and so forth—were mainly owned by foreign nationals of German descent. The largest industries as a whole were outside the national domain although located within its territory, primarily in Valdivia.³⁰¹ For example, the German *Compania Industrial*, which paid dividends of 21% in 1908, had been capitalized at \$2.5M. Large German-owned plants, like the

Refineria de Penco processed 15,000 tons of raw sugar in a year; rivals produced 2,500 tons of pure sugar per year. In 1908, German tanning industries prepared most of 27M pesos worth of cueros, exporting 3M pesos in that same year to Germany. Luis Rudloff's shoe firm produced 700 pairs of shoes per day, and had 100 employees. German industries seem to have mainly hired German workers, as the case of Vina del Mar attests.³⁰²

These foreign owned industrial enclaves across the Chilean economy show that science-economy interactions were not fully dispersed throughout the society, but that instead, these had greater connections to European nations. The industrial strands which would have naturally stimulated scientific development, and in turn economic development, were more closely linked to Germany and England than to Chile. Had Chileans controlled larger sectors of chemical-related industries, the "economic pull" to developing her chemistry would have been much greater.

The causes for this can be attributed to all participants, including Chileans themselves.³⁰³ It is likely that, fueled by increasing capital reserves from its growing industries at the turn of the century, Germany like Britain during the latter half of the century, sought foreign investments. More importantly, however, is that Chile, like Argentina, had begun a process of industrialization by immigration. While these social policies brought new techniques and tools into the country, it did not seem to lead to the same kind of technological transfer as that which had occurred in the United States during the eighteenth century. While Chileans would not become near-minorities in their country, as had occurred in Buenos Aires, their attempts to modernize further weakened their economic influence because there was no direct transfer into Chilean hands. While Chilean immigration policies were relatively selective, they do not seem to have been selective enough.

There seems to have been other reasons for Chilean policies, private and public, towards nitrogen fixation. One of these is that Chile suffered from a "small-state" syndrome. In this sense, Chilean industrialists, government leaders, and scientists were all constrained by broader social forces entirely beyond their control. Although they tried to modernize, and the economy did have some pull towards this modernization process, there were other complementary economic and political forces inhibiting the process as well. The confluence of these rival trends of its history only seem to reinforce the broader patterns which have been generalized from case analyses of other countries in similar situations.

It is clear that Chile was influenced by small-state dynamics throughout the century, even if nowadays she is considered a borderline state.³⁰⁴ Chile simply did

not pursue an aggressively offensive policy, a trait all too typical of the vulnerable small state. Regardless of the legal equality of all states, large states simply have a much wider range of means for achieving their goals. Their large internal markets usually mean that they will be less amenable to economic coercion than small states that usually have to rely to a much greater extent on exports to generate the capital needed to purchase goods produced elsewhere. Their small internal market and labor force is not large enough for the diversification found in the large state; it cannot be a miniature of its larger counterpart. This tendency towards a monoculture export economy is clearly seen in Chile, where at any one given period, one product has consumed the majority of its income. This economic vulnerability on behalf of the small state generally means that they cannot afford to take aggressive stances, which might place large states into offensive positions. While Chile certainly could afford to go to war with rival weak states like Peru and Bolivia, theory suggests that she could not take such a stance in the international economic realm.³⁰⁵

Although the case of the Netherlands shows that it is not impossible for a small state to enter a capital-intensive goods market as the chemical industry is, the large financing needed for such ventures generally means that few such nations ever become producers for the market. The capital sums that are required to eventually produce any one single item can sometimes be larger than the total yearly net income of a single small state; in this sense it is true that the multinational corporation rivals the nation as an organizational entity. The synthesis of indigo, for example, eventually cost a total of about 20 million DM between 1880 and 1897, and involved the work of hundreds of scientists at BASF, Hoechst, and Bayer. The two main processes of cracking petroleum had cost at least \$15M to discover. These large expenditures are true for the work on ammonia synthesis as well. Between 1908-1918 Dupont had spent \$30M in ammonia and related technologies, while the U.S. government itself spent \$127M in research and the two Niagara plants—which ultimately produced only minor amounts of the substance.³⁰⁶

Because of its costs, only large firms can undertake significant research and development. In 1970, U.S. firms with more than 5,000 employees made up 89% of all industrial R&D investment, and the figure had grown to 90% by 1978. The general pattern can also be noted in a smaller nation like Japan in which firms with more than 3,000 employees made up two-thirds of the total industrial R&D between 1978 and 1979. Even when we consider only the cost of plant construction, the price needed to establish a 1,000-ton per day ammonia plant is not cheap either, being \$30M in 1970 and \$80M in 1980. The sum is

actually larger than it appears when one considers that the size norm after 1964 was a plant of 1,500 tons per day.³⁰⁷

We may note, however, that plentiful resources tend to encourage waste in the large state. Fritz Haber once told a U.S. host that while U.S. laboratories could afford to get eight failed experiments out of ten, two such experiments in Germany would be seen as a catastrophe because of its limited resources. We need not assume that large expenditures need prohibit the entry of the small state into business sectors like the chemical industry. Many small countries as Israel have developed such local industries, albeit under strained conditions.³⁰⁸ Korea's successful entry into the field between 1961 and 1966 perhaps serves as a model, even if the \$200M in plants operated at 40% of world capacity level. She also suffered similar problems to that of Chile in that complementary industries did not exist to purchase its chemical output. Yet Korea's export of ammonia increased from 61 Th. ton in 1970 to 327 Th. ton by 1981. We also need not assume that a large state can by default be a member of the chemical industry's community either. Some large nations as Brazil may simply lack the basic feedstocks for ammonia synthesis as natural gas to enter the field—a resource readily available in Chile's southern cone.³⁰⁹

We may also point out that while small nations certainly cannot afford to enter the field when its technologies are nascent, because of their incredibly high R&D costs, they can afford to enter the market once these technologies have already been developed—a “defense” stance described by Freeman. Most firms, even when they have the means to pursue more offensive stances, prefer to take this parasitic approach. Because of the ambiguities in the patent system, a company can make a number of relatively small changes on a truly new product and market it as its own—in the process reducing costs of production and the uncertainties associated with new products. While this stains the character of a corporation in the first world, such is not the case with corporation in LDC's where much of the preexisting managerial, technical, and scientific know-how is usually previously lacking. It is simply more moral and cheaper to enter non-intermediates late in the game; the innovator by then will have accrued substantial profits and lost many initial market advantages as a result of standardization. That basic products such as ammonia tend to have a much wider number of processes and producers only favors the recipient in the licensing process.³¹⁰

We may thus reorient our question. If it was nearly impossible for Chile to have entered the industrial process of synthetic ammonia prior to W.W.I, why did it take her about sixty years before she even broached the subject? It seems like she could have entered the field at around the time when Japan had in the

1950's given the increased size of the chemical community and the infrastructures which had been built as a result of her nitrate wealth. Although a detailed analysis is needed to faithfully answer this question, the above data again suggest our initial answer—she simply lacked the will to do so.

Instead of acting like an innovative and independent state, she preferred to follow trends only when these showed themselves in the international community. Perhaps the Latin American framework had much to do with it. Although all such nations began industrialization long before Asian countries had, they have been far surpassed by their oriental competitors. Culture is an important component of industrial behavior, as Lipsett had long ago shown. Chile continued to be confidentially assured of her mineral-based wealth rather than actively trying to breach this Spanish economic paradigm—even when minerals had not constituted the primary source of wealth during the colonial period. The economic structure created a social system, which encouraged a particular attitude towards nature, and in turn reinforced its economic structure in a vicious cycle—a pattern described by Safford. The *longue duree* of history can be surprisingly persistent.³¹¹



The economic stimulus that Chilean chemistry felt because of its primary industry can also be observed in the case of Argentina. Yet instead of the relation observed between the sodium nitrate industry and the development of its physical chemistry, one may observe the stimulus that the study of colloids received from the prominent agricultural economy, in particular the growth of its beef exports. We also may note the first hints of a future petroleum industry, and the impact it was beginning to have on its science can also be traced—however faint the nascent relation at the time was. This section, in contrast to the previous one, will limit itself only to describing such economic-scientific relations rather than fully tracing them as was done in the previous section.

Cattle permeate Argentinean culture as much as it has that of Texas, but with its own unique flavoring. A Spanish accidental introduction that broke loose in the vast Pampas plains whose grasses were as tall as those of a fully-grown cornfield, this herbivore had amply and successfully reproduced in a rather favorable environment. During much of the nineteenth century, its only predation by man, the gaucho, was on a relatively small scale. Charles Darwin, who had visited the region in his travels aboard the H.M.S. Beagle at mid century, described this culture as a barbarous one. Any minor insult would quickly lead men to pull out

their knives, they lived in shacks as rustic as the Puerto Rican bohio, and they were entirely without a clue as to the direction in which London lay—the last which greatly surprised and possibly offended the yet unknown naturalist.³¹² During the Peron years of the 1920's, the gaucho's image would become that of an idealized national hero. His "bollo" became a symbol of his manual dexterity, physical prowess, and manhood.

Yet it would be the use of the barbed wire (1845), the introduction of refrigeration (1870) and the spread of railroad lines at the turn of the century would terminate the gaucho's era, transforming the region into an abundant and rationally ordered "breadbasket". Although they would not industrialize Argentina, they would provide her with a great deal of wealth, aptly fitting the nation into John Stuart Mill's schemata of national economic specialization. The gaucho, much like the Texas cowboy, would ultimately be relegated into myths that idealized that individualist ethos of bygone economies—values that were no longer fully applicable to its own however great the longing might have been.

Its financial statistics reveal much about the economic forces redefining Argentinean culture. In 1900 it was exporting 2M gold pesos worth of frozen meat; by 1934 the number had risen to 33M gold pesos. In actual weight this represented around 500 thousand tons of frozen beef in 1918 and 400 thousand tons of chilled beef in 1925. While in 1915 1.4M heads of cattle were slaughtered, by 1925 the number had almost doubled to 3.1M. Between 1900 and 1904, livestock products had made up 33% of the 10.8B pesos (1950's value) of Argentinean exports. That the price of this export rose by 90% between 1899 and 1914 must have provided the kind of boost the computer industry has recently produced in the U.S. economy. While the total percentage of these and other agricultural exports declined from 91.9% to 64.5% between 1891 and 1930, it is clear that meats formed the bread and butter of the nation, whose total export tonnage increased throughout the period. Besides cattle, it also included 70M heads of sheep in 1884, a 203% increase from 1864, which generated \$31M of exports in 1883. By the time the 1PASC was held, Argentina was still primarily an agricultural export nation. Not surprisingly, its influence was felt at the congress.³¹³

Of the 14 Argentinean presentations in chemistry, only one could be claimed to having been in "pure" basic science with no particular tie to any given industry. Of these, the largest single grouping, seven, had to do with the chemistry of casein, albumin, or flour—much of it being mainly colloidal chemistry. It may not be immediately apparent what the exact ties are between the science and it's

related industry are until a little further digging is done. Both casein and albumin are livestock products.

Casein is a substance found in milk at 3% of the total mass, milk being a mixture of finely divided suspended particles referred to as colloids. It was of some commercial interest prior to W.W.II. Used in the making of household paints, the U.S. actually imported 19M lbs in 1917 from Argentina—a trade balance that had changed by 1937. But casein is also an albumin, a word used to describe general category of proteins.

Albumin is a water-soluble protein readily found across most living species, plant and animal, of the world. That in blood was used by Prussia (pre modern Germany) in the eighteenth century to make blue dyes. Since it is a protein, and proteins contain the NH_2 amino group, it behaves similarly the azo group (N_2) of compounds similar to aniline, which formed the basis for a wide variety of synthetic dyes.³¹⁴ The mixture of nitrous acid and aniline set off a series of social chain reactions eventually leading to the formation of BASF, the firm first to utilize Haber's methods to develop the first such ammonia plant. It was this material so readily found in livestock products, albumin, which received the greatest attention by Argentinean chemists.³¹⁵

Relatively minor, but not unimportant, experiments consisted mainly of trying to find out more information about a substance's physical properties. These experiments were not testing hypotheses but mainly gathering factual data that would hopefully prove useful sometime in the future. As such, they resembled many of the studies that had ties to the future petroleum industry, which will be discussed later. The aim to research economically valuable substances were rather openly and explicitly made by the scientists involved.

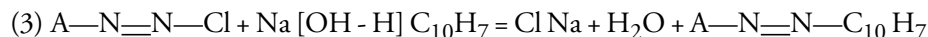
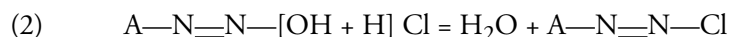
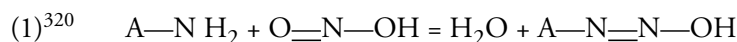
The research conducted for the local agriculture ministry by Enrique Herrero Ducloux gathered information on butter's heat of combustion, which he believed could be used as a test of its quality. He found that the value varied between 9.878,8 and 9.787,1 calories per gram, that its index of refraction at 40°C was 1.4545, and that its index of "saponifiacion" was 225. Dr. Martiniano Leguizamon also sought to find similar physical constants, but for the "aceite de madera de la China." Oils protect wood because they bonded with oxygen to "saturar sus valencias libres". Despite its economic value little was known of its properties. Leguizamon, "Quimico de Primera de la Oficina Quimica Nacional de Buenos Aires," found 18 different traits, such as that its freezing point was -16°C , chloride had no effect, and that it had no H_2S , rather uncommon for an oil of its kind. Similarly, the "seda de caseina" had such a large trade at 33M kilos per year, that Leguizamon also believed, "su estudio y la invetigacion de sus constantes ten-

dria un doble interes industrial y cientifico.” The artificial silk turned violet under cold hydrochloric and sulfuric acids, intensely yellow under “Licor de Millon”, but dissolved under acetic acid.³¹⁶

Yet there was another category of experiments of a much higher quality in terms of originality. As Ducloux mentioned in his report, “No, la ciencia argentina tiene medula y es algo mas que un reflejo palido de la ciencia europea; la nueva generacion de hombres de estudio merece ser considerada en el mundo intelectual.”³¹⁷ The four presentations by Horacio Damianovich are perhaps the most interesting not only because we witness the active testing of novel theories but also because they dealt with one of the region’s most prominent products, albumin.

Damianovich, who worked at the laboratory of the Oficina Quimica Nacional de Buenos Aires, explained that there were many different ways of studying proteins. One of the problems with the typical analysis-synthesis method was that it destroyed the protein involved, although revealing some of its component amino acids. He believed that the most fruitful approach to organic chemistry lay in altering the physical structure of the protein without actually destroying it—in other words, making it react with other substances gave a clue as to its internal structure. According to him the method was still in its infancy. “El arduo problema que envuelve la tan discutida constitucion de los albuminoides, a pesar de los numerosos trabajos hechos en estos ultimos dos anos, esta muy lejos de ser resuelto”.³¹⁸ The world of the physicist and that of the chemist were not that different after all.

One particular experiment mainly consisted of turning egg albumin into a red dye.³¹⁹ This was achieved by mixing it with (1) a solution of sodium nitrite, (2) hydrochloric acid, and (3) phenol-like alpha-naftol in a consecutive series of stages which were later interpreted by Damianovich by the following equations:



He believed that the first mixture produced the basic azo group ($\text{—N}=\text{N—}$) or “diazo albuminoidea”, which then served as the foundation for the consequent reactions. That he was able to chemically manipulate it to eventually obtain a well-known substance of azo dyes showed that similar procedures had taken place as those when phenol is treated with nitric acid. When the albumin in wool or

milk (casein) is similarly treated, a red dye is also obtained. It was important to note that the effect of light after treatment with sodium nitrite in stage (1) could prevent the phenol binding in stage (3), thereby altering the experiment's results, which had been undertaken in a camera oscura. To make certain, many other tests as those in spectroscopy needed to be undertaken on the substances to verify the accurate representations of his equations.³²¹

In other experiments, Damianovich believed he could model the process of cell division and the interaction of Faraday's lines of force by an interesting combination of dyes. Placed on a gelatinous base, the various dyes would either repel or attract one another, producing a photograph, which surprisingly did resemble the biological and magnetic counterpart. Violet and green dyes attracted each other, while green and fuscina had the opposite effect. Although the experiment did not consist in studying the actual material of consideration, by their similar behavior Damianovich believed the experiment could shed light into these processes.³²² He did not explore what that insight might be. The scientific merit of this one particular experiment is highly questionable however interesting its philosophical foundations or visual effects might have been. This contrasted to his studies of the direct influence which colloidal dyes had on germination and microorganisms, many of which died upon exposure because the living tissue's albumin was reacting with the dye's compounds.³²³

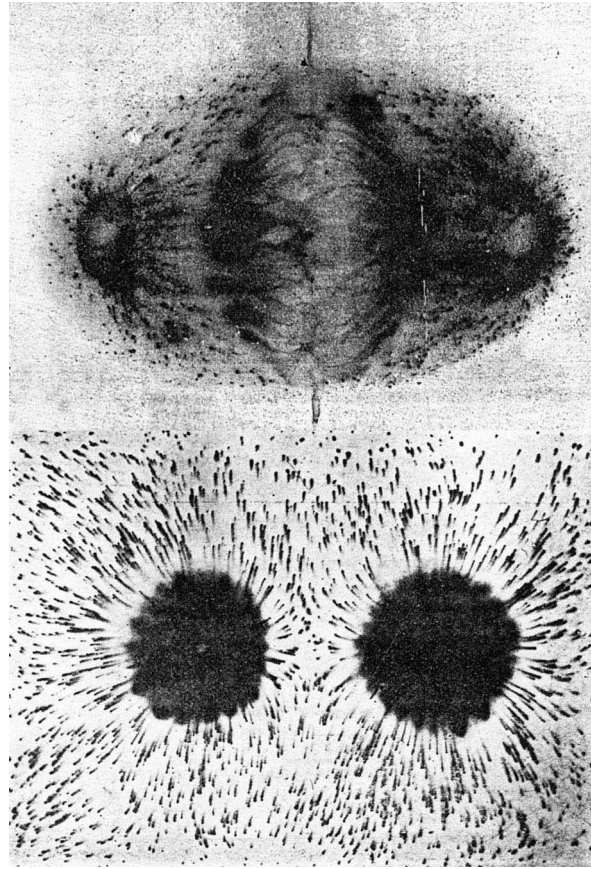


Figure 26: Faraday lines and mitosis modeling (Damianovich)

We may draw some brief comparisons between colloidal science and the cattle business in Argentina to the science-economy interactions in Germany. Could these researches have lead to a revolution in the Argentinean economy with corporations the likes of an IG Farben? The above information suggests that it was not a likely possibility. The German economic miracle rested on its plentiful foundations of coal resources. Organic chemistry was highly valuable precisely because, through its discoveries, it was able to transform these plentiful mineral resources into such tangible commodities as dyes, fertilizers, etc. The case of Argentina, however, showed the opposite pattern. Complex tissue from living animals—chickens, sheep, or cattle—could obviously not have lead to the same economies of scale. Whether from coal, oil, or natural gas, the underlying mate-

rial foundation had already been created and man just needed to chemically tap into these resources for its supplies. In the case of animals, which had to be grown, fed, and medically treated, the input-output schemata simply disfavored its wide implementation if such had been the intent.

Nonetheless, we may conclude from the previous examples that an economic impetus, a “social construction”, was stimulating the development of its organic and colloidal chemistry. Yet, it cannot be argued that it was of its extreme and rigid “strong” form.³²⁴ As the scientists themselves admitted, they were purposefully choosing to undertake such research venues; it was not the result of some deep and underlying forces they were unaware of but was rather the result their own willful action. As such, the example suggests that “internalist” and “externalist” arguments are not mutually exclusive. A scientist might be affected by society only because he consciously chooses to be so affected.

There is further evidence for this conclusion. Long before the influence of a particular industry could make itself felt in the economy, scientists were already gearing their research towards that industry. In other words, they consciously organized their activities towards goals, which would help insure the successful development of an industry yet born. Because it was a willful activity, it would not have to wait until the industry emerged before it began to act. Nowhere is the dynamic more clearly seen than in the case of Argentina’s petroleum industry.

Argentina in 1908 did not have a petroleum industry, either foreign or natively run. The largest site at Comodoro Rivadavia in the southern state of Chubut had only been discovered the previous year (1907). It would show proven reserves of 136.4 million cubic meters in 1969 and yield 1 billion barrels of oil by 1982. Yet the site would not be immediately developed because Argentina lacked the means, while those nations with the means, such as the U.S., lacked the will to do so.

Although Standard Oil Co. was the largest such trust in the world at the time, it simply had little incentives to explore and exploit the reserves near La Plata prior to W.W.I. The company was successfully building its own domestic industry, riding a wave of demand stimulated by the affordable Ford automobile introduced in 1904. In contrast to those in smaller nations like Britain or Belgium, companies in large nations like the U.S. need not be imperialistic nor expansionary outside their borders simply because there is already much to be gained within the local market, as previously mentioned. The efficient transportation system of the railroads, the plentiful amount of raw materials, and a favorable business environment provided many of the “carrots” that kept Standard within U.S. territory. By 1904, it was already producing 84.7 % of the U.S. total petro-

leum production at a tremendous profit. With these gains, there is simply no financial motive to go abroad. The corporation as well as the nation could self-assuredly retain its isolationist stance without any need to worry about harmful repercussions.

It was only when these carrots began to wither away, as occurred when the Sherman Antitrust Act of 1911 removed Standard's reserves, that the company began to look abroad for business opportunities. The war also helped many realize that it was not in the national self-interest to use up its own reserves; it was better to save these for a rainy day. Argentina in 1908 was an oil-importing nation, not an exporting or self-sufficient one.³²⁵

"Miraculously" (within a social constructivist schema), however, the influence of a yet-to-be-born petroleum industry made itself felt at the IPASC. Like many atomic mysteries in quantum physics, our subject had reacted prior to the appearance of its object. Our historical case, however, only seems miraculous because it has been inappropriately contextualized.

The most obvious scientific presentation related to the petroleum industry is that by Ernesto Longobardi who was presenting a relatively unoriginal chapter from his doctoral dissertation. Longobardi, a member of the "Oficina Quimica Nacional de Buenos Aires," surveyed the sites throughout Argentina where the resource had been found: Jujuy, Salta, Mendoza, Neuquen, and Chubut.³²⁶

Other presentations, such as Ducloux's in hydrology, do not immediately reveal their connection to that industry, and not even George Philips who wrote a rather lengthy history of the oil industry in Latin America, was able to detect it.³²⁷ Like his previous presentations of physical constants, Ducloux merely provided data on the physical and chemical state of the nation's rivers and lakes. For example, we find that in the province of Catamarca, a mountainous region close to the northern border of Chile, trace elements in its water included nitric-sulfuric-boric acids, aluminum-calcium-potassium oxides, ammonia, iron-magnesium "carbonatos", and so forth. Jorge Magnin's lecture on filtrating solutions of sulfur may also not appear to be directly related to the petroleum industry.³²⁸

However, when one considers that, in contrast to our era, most wells in 1900 were "shallow" at 2,500 feet below ground, and that sulfur is an ever-present ingredient in petroleum, the connection becomes clearer.³²⁹ Identifying water sources with a high sulfuric content gave an indication as to the presence of petroleum saturating the underlying ground. As Longobardi explained, it was this process which had been used to identify sites such as those in Salta. When Brackenbusch had traveled to the neighboring province of Jujuy in 1881, he called, "la atencion [a] la existencia de fuentes de agua sulfurosa cerca de los puntos donde el

petroleo surgia del suelo en forma de un alquitran negro...” Even though the reserves eventually developed in this northern region were much smaller than those in Rivadavia, they were large enough to eventually stimulate Standard’s purchase of 22,000 hectares during the 1920’s.³³⁰ Ducloux’s comprehensive surveys, which mentions studies of Rivadavia of 1906, can thus be regarded as contributing to Argentina’s both cattle and petroleum industries. The economic-scientific link is rather clear.³³¹

If we are to criticize anyone, however, it is not the U.S. oil industry but rather these Latin American scientists for their naiveté. Prior to the 1990’s, exploration constituted the industry’s highest costs and risks. J Stanley Clark, a promoter of the industry, explained that the deeper a firm had to drill in its search for oil, the costs increased from \$20.54 per foot to \$105.91 below 15,000 feet. “Not only is exploration highly speculative and costly, but production does not necessarily assure great profit.”³³²

Scientists like Ducloux and Languizamon did not realize that by readily providing such information, they greatly reduced the cost and risk to the U.S. oil industry by a very large and inestimable margin. It was an intangible profit that could not be taxed or charged by Argentina because it involved the reduction of corporate costs which would not take place because of the information transfer itself; without it, Standard would have had to expend a vastly greater number of resources than it actually did. Looking for a needle in a haystack is not difficult when one is handed the needle by someone else. We may easily argue that before Augusto Bunge criticized Standard in Salta for having monopolized local territory, the “crime” had already long been committed.

By the late 1920’s when Bunge filed his lawsuit against the company, Standard’s territorial acquisitions could not really be criticized because it was mainly a defensive posture. As many foreign oil companies had experienced in Mexico, landowners tended to radically hike land prices with the growth of the industry.³³³ Only by buying territory prior to the appearance of public awareness of its petroleum resources could Standard achieve viable costs of production. Ironically, it was precisely because the economic realm had not yet fully manifested itself in the scientific, that the industry would gain tremendous concessions from the scientific spirit and belief in the free exchange of knowledge and information.

Yet Latin American scientists freely provided that information only because they were acting as scientists treated one another; they simply “did not know any better”. Despite the fact that the congresses were not meant to foster basic science per se, the attitudes and values that characterized the Pan American Scientific Congresses and its more narrowly defined predecessors. They openly and freely

presented the results of their research, from which most foreign observers, British, French, and North American, greatly benefited. Many local participants did not realize that such values conflicted with the congresses explicit goals: practical applications to the Latin economy. Somewhat paradoxically, these cases show that although Latin American scientists tried to be “technicians”, they could not help but be “scientific”.

5

Technological Scientism:



Factor variables in the diffusion and development of science in Latin America

*“New Spain did not seek or invent;
it applied and adapted.”*

—Octavio Paz

Two apparently conflicting-but-valid observations can be made pertaining to the PASCs impact. On the one hand, the PASCs do not seem to have a long-term impact on the region. Even when it inspired some hope for the future, the intellectual tendencies prior to the congress were not significantly altered. A full-fledged discontinuous “scientific revolution” did not emerge. Although some institutes and research agendas were initiated, there appears to have been no significant change in the scientific style of the region until the Second World War. Certainly there were a few leading exceptions who participated in the PASCs, but they were the exception. Latin American nations did not achieve what George Basalla has termed a “take-off” stage, but they only made the existing science available for practical purposes: the gathering information on earthquakes, the creation of standardized time zones, etc. This is not to suggest that the two aims are incompatible. However, that the same proposals were made congress after congress suggests that despite repeated calls for change, little real progress was being made even at these more simple levels. There seems to have been no attempt to develop a progressive and continually developing science.

On the other hand, there can be no doubt that the congresses were successful in transmitting the latest scientific research to Latin America. The entry of the United States into the congresses significantly raised the quality of the science discussed in the congresses when we compare these to the preceding LASCs. As

such, the new “panamericanism” was not unlike the scientific revolution initiated by Bailey K. Ashford in Puerto Rico.³³⁴ It opened new vistas and opportunities even though it did not change the island overnight. A. A. Michelson gave his audience the means that had recently revolutionized physics, astronomy, and chemistry: spectroscopy. H. D. Curtis discussed new techniques that were helping to establish the nature of the cosmos, even though these would not culminate until Hubble’s work in 1925. W. B. Smith discussed some of the latest advances in the new physics pertaining to the structure of the atom—again work which would not be consolidated until Bohr’s 1911 masterpiece. In chemistry, Monroe warned of new nitrogen fixation processes that had in the same year been discovered by Haber in Germany. These are but a few of many examples in which Latin America directly benefited from U.S. involvement—benefits from a nation which had only recently become the near equal of its European scientific counterpart.

How do we resolve the disparity between these two observations? What happened in between?

Our conclusions as to the success of the PASCs depend, in part, upon how the word “diffusion” is defined. If one uses the term in its strict definition, an exchange of information whereby the recipient gains an awareness of new ideas and approaches, then one can say that the PASCs did indeed have a tremendous impact on the region. It brought into contact the leading minds of the two regions, wherein each shared with the other the best they had to offer. The PASCs achieved what it was meant to achieve, and in some ways that is all that can be fairly judged about the congresses *per se*.

We may also point out that any conclusions reached in this study apply mainly to Chile, which was followed at some depth in contrast to other nations. A more comprehensive study would include other countries, but the author does not believe this would significantly alter the conclusions herein found. Despite the many similarities between Latin American nations, southern cone countries at the turn of the century seem to have scientifically outpaced their neighbors because of their favorable immigration policies, in particular with respect to German citizens.³³⁵ As the PASCs showed, the gap was not a wide one as that between science in Europe to that of China or Africa, but rather a much smaller one between Europe and Europeanized states. Local scientists produced relatively significant work: Latin-Americanized Europeans as Marcel Lachaud proposed ingenious solutions to problems which had perplexed the world of physics and Europeanized natives such as Bernardo Diaz Ossa inquired into the properties of “salitre”. That it is relatively hard to differentiate the quality of the two men’s work, a foreigner and a local, attests to the similarity of its quality.

This reduced scientific lag meant that if the PASCs were to have had an effect in encouraging the “take off” of science in Latin America, it would have most likely been observed in either of these southern cone countries.³³⁶ Yet, more importantly, this again raises the troubling question as to why, if the transfer of information between nations at a relatively close parity had occurred, did the process not later make Latin American nations as Chile viable competitors in the twentieth century scientific race? That such would not happen in Chile until around W.W.II for both physics and chemistry indicates that the PASCs had not been enough of a stimulus for the region as a whole. The same might even be said of Argentina, but less so. How can we explain it?³³⁷

Many models have been proposed to account for the “spread of western science”. How illuminating are they of our historical case study? George Basalla’s is perhaps one of the most cited in the literature. How would we situate Chile in the Basallian three stage model, and what can it tell us about these processes? Like water that under certain conditions can be in all three physical states at once, Chile appears to have been in all three stages in 1908.

Obviously, there can be no doubt that the first stage of colonial science existed. As we have seen, there was a tremendous emphasis on the practical, and the majority of practitioners were not native but rather foreign German émigrés. Little prominence was given to purely theoretical science, and by far, the greatest emphasis was on biology, geology, and astronomy—the latter that was used mainly for its cartographic function. This would be the predominant characterization of the period.

It is clear, also, that Chile was moving into greater scientific independence—Basalla’s second stage. There were emerging scientific heroes who attempted to compete with the metropolis, however failed such attempts had been. Here the role of the foreigner is a little bit harder to discern, and it is not quite as clear-cut as Basalla would have us believe. While the likes of a Ristenpart, who published mainly in Germany and entirely identified with the scientific processes in the metropolis, fits more into the first stage, a man like Obrecht clearly does not. Obrecht had become Chilean in the sense that he identified mainly with the periphery. For example, he did not publish abroad but mainly within the region’s journals, his work was devoted for the sake of the state rather than science, and there was a clear strong local orientation in his scientific rhetoric. Although he was of French descent and had been trained in that metropolis, he had become a peripheral scientist for all sakes and purposes. A similar process seems to have happened with Lachaud.³³⁸ We also find that increased educational funding and the emergence of national scientific congresses (and international

ones like the IPASC) were clear indications that Chile sought to establish scientific centers at home. It had been firmly fixed in the second stage. But, had Chile entered a Basallian scientific “take off” stage? It had not.

While obviously Chile had not entered the third stage in the sense that it was not producing scientific knowledge of recognition in the world stage, there were deep economic undercurrents pushing it in that direction. In contrast to Australia whose economic recession had undermined her extractive economy in 1890, Chile at the turn of the century was entering a period of economic prosperity based on her nitrate mineral deposits.³³⁹ It was very clear that this economy had provided what Ian Inkster has identified as an infrastructure (whether cultural, institutional, or economic) underlining its scientific activities. Men like Diaz Ossa, Pablo Moriozot and Juan Rochefort were clearly stimulated by a scientific drive largely independent of any internal psychological impetus that may have emerged from international scientific competition as described by Gynicki. The “externalist” economy provided an “internalist” motivation entirely independent of the “external” relation to the “internal” invisible colleges of science. In other words, this was a take-off stage to some degree because it was thusly stimulated regardless of what its international position may have been vis a vis other scientific powers; a peripheral self-identity in this sense did not make a prominent negative part of the mental construct of the Chilean chemist. This does not seem to have been the case for the Chilean physicist.³⁴⁰

Yet, this is all that Basalla’s model tells us about the process. The model is problematic because of its rather vague structure. There is little within the model to account for the internal dynamics of these processes, however well it may aptly describe the overall schemata.³⁴¹ Lewis Pyenson’s early studies of Latin America are also highly suggestive. The “incomplete transmission” described of Buenos Aires at the turn of the century is a highly appropriate characterization to the science found at turn of the century Santiago, and they do share many similarities.³⁴² But like Basalla’s work, it is unfortunate that the case was not more carefully developed into a more rigorous theoretical framework in his later writings which received a good deal of criticism.³⁴³ Other models, although also suggestive, deal too strictly with generalities rather than with the actual means by which science advances. They do not have the level of factual detail necessary for a more “realistic” assessment of the process. There seems to be one exception, however.³⁴⁴

If there is a “model” that most useful in the analysis of our topic, it seems to be that by R.G.A. Dolby published in 1977—a model rarely cited in the literature and which has been grossly overlooked.³⁴⁵

Dolby explained that the transmission of ideas was not necessarily akin to the diffusion of science—a problem that had also beset early studies in the history of technology.³⁴⁶ It is an important distinction, analogous to that made in technology between the invention and innovation of a technology or technique. Until new ideas are incorporated into actual research in a new locale, one cannot claim that the idea has yet diffused into that region. Practice, not presence, is the sole criteria of transmission. His article describes the factors that would affect, positively or negatively, this shift from the diffusion of an idea to its exploration within a peripheral community. As such, the model helps account for the different shifting traits in the Basallian model, and in turn our case study.

Before fully discussing Dolby's model, however, the chapter will first describe many of the pervasive inhibitory factors that could be observed throughout the primary sources. While some of these have been hinted at in previous chapters, they will be more fully discussed here. These will then be integrated within Dolby's schema to hopefully present a more rigorous explanation for the "why not" of Latin American science.



The scientific congresses showed that although Latin American scientists were becoming more professionalized, the practice of science was still dominated by professionals in well-established, but low-risk and highly-remunerative fields outside of science per se: medicine, law, and engineering. In other words, Latin Americans at the turn of the century did not generally choose science as a vocation—a problem which had also affected French chemistry in the same period and which was obviously typical in England during the Scientific Revolution.³⁴⁷ It is clear that this trait had a tremendous impact on the growth of science as an institutional and intellectual body in the region. The smaller number of individuals dedicated to science, the slower would its progress be as a set of ideas. It could be seen across all LASCs-PASCs.

The ILASC was entirely dominated by professional men. While engineers generally presented works in mathematics, doctors usually addressed natural history. For example, the engineers Federico Villarreal of Peru, Eugenio Tornow, and Carlos Honore presented works on "Geometrias no euclideanas", "Nuevos metodos de division de poligonos", and gravity respectively. Doctors like Carlos Berg and Eduardo L. Holmberg gave lectures on "Nuevos datos referentes al cultivo de hongos por las hormigas fitofagas" and "La fauna argentina". Their examples are the norm. It is also interesting to note that all members of the executive

committee also belonged to one of these professions. There were very few “scientists” per se.³⁴⁸

The 2LASC showed the same pattern. During the opening session those who spoke were related somehow or other to medicine: Prof. Jose Arechavaleta, president of Organizing committee, Dr. Roberto Wernicke, Doctor Manuel B. Otero, Doctor Cornado, Dr. Victorino Pereira, Doctor Emilio Pimentel, Doctor Pablo Patron, Dr. Cecilio Baez, and finally Dr. Cobos. Of the 31 member executive committee of that same congress, there were 14 doctors, 7 lawyers and 5 engineers, totaling 70%.³⁴⁹ Similarly, 73% of those in the organizing committee of the 3LASC had also belonged to the same groups. There were no scientific associations per se representing Venezuela in that congress.³⁵⁰ Of the 11 names mentioned for the biology section of the 1910 LASC, seven of these were physicians, and only four were formal university professors.

Not surprisingly, 1PASC/4LASC also showed the similar prominence of professionals. Of the 1,850 delegates surveyed by Poirier, the majority had been men, 94%, who were lawyers (20%), engineers (18%), or doctors (17%) totaling 55%. It might be said that there were many more scientists in this congress than in previous ones because there were that more individuals involved as a whole. Such, however, would be to mischaracterize level to which science had become professionalized. While the overall distribution structure was certainly beginning to shift towards the increasing professionalization of scientific disciplines, only 21% the total had been formal university professors. In contrast to our era, the number remains incredibly low. One cannot imagine a conference now days where the formal members of a profession would be the minority party in its own yearly gathering.³⁵¹

We may also note that Latin Americans at the turn of the century did not seem to value science as a field of scholarly endeavor, as the case of Chile so well attests. A survey of authors in the *Anales de la Universidad de Chile* between 1900 and 1930 reveal that there was an ethnic division pertaining to choice of topics.³⁵² While most Germans authored scientific articles, 78.91%, most Chileans preferred humanities related topics, at 79.79%. It is indeed remarkable the degree to which each ethnic group inversely mirrored each other. While Chileans showed a strong disfavor of science, with only 21.05% members authoring such articles, Germans inversely also showed the same negative propensity in the humanities, at 20.21%. Approximately the same figures appear between 1888 and 1899: 82.18% of science articles were of German authorship, while 75.48% of humanities articles were by Chileans. C. P. Snow’s two-cultures paradigm was structured not only across disciplinary lines, but also across cultural groups that

almost identically followed these disciplinary divisions. It is easy to see why prejudiced “culturalist” (as opposed to “racist”) statements might have arisen as a result.³⁵³

Discipline	Chile Origin	German Origin
Science	35 (21%)	131 (79%)
Humanities	229 (80%)	58 (20%)
Medicine/Technology	44	10

Table 3: Distribution by nationality of authors in the *Anales*, 1899-1930.

A study of university degrees awarded in Chile show the same trends pertaining to local values. There was an equally strong propensity towards humanities by Chilean students, as opposed to scientific degrees. Between 1890 and 1921, only a total of 4.72% of the degrees awarded were in science (not including engineering or medicine) as opposed to the significantly larger humanities figure of 74.41%. Since the numbers in science fluctuated between a low of 1% to 11%, in 1920 and 1904 respectively, there even seems to have been a decline rather than an increase in the number of Chilean students in science.³⁵⁴ Improvements made during the Balmaceda period seem to have gradually withered away.³⁵⁵

Year	Science	Humanities	Technology	Medicine
1890	26	379	15	56
1891	19	280	3	59
1892	43	406	3	100
1900	43	354	12	83
1901	33	379	17	63
1902	33	321	12	47
1903	32	365	16	66
1904 (a)	45	282	4	47
1904 (b)	15	115	4	39
1919	58	1135	35	246
1920	20	1004	43	316
1921	23	1128	44	368

Table 4: Distribution of B.A. of the University of Chile by topic, (1890-1921).

The Latin American value structure with a greater emphasis on practical application could also be traced throughout the internal contents of the congress’s lectures and meetings. Basic science, or what most would term as “science” per se, was oddly not valued by the delegates themselves in that it was not structured in the uppermost tier of the congresses’ main priorities. These assumptions, explicit

and implicit, are pervasive throughout the documents. Given the predominant professional orientation of its organizers and delegates, this should perhaps not be surprising.

For example, although the congresses had multiple purposes such as the improvement of diplomatic relations between all countries involved, the predominant emphasis had been on the finding of practical solutions to problems unique to the region. As Leo Rowe commented, the congresses had been formed “for the purpose of comparing the results of their investigations, and exchanging views as to the best solution of the political, social, educational, and engineering problems peculiar to North and South America.... The keynote of all the sessions was the emphasis laid on these distinctively American problems.” The “Santiago congress” showed that all scientific research in Latin America, “is being directly primarily to the solution of the distinctively national problems” As may be observed, the emphasis is not placed in extending the frontiers of knowledge, but rather in applying this existing base.³⁵⁶

It was clear that Rowe was echoing what had already been informed to him by the 1PASC organizing committee. During preceding deliberations, the committee sent a letter to Rowe informing him that the purpose of the congress had been “en formar en este continente una mentalidad americana con lineas definidas y tendencias propias, capaz por si sola de dar solucion a muchos problemas que por ser, netamente de indole americana, han menester ser estudiados y resueltos...” This emphasis could also be seen at the 3LASC. Prior to attaining a position of importance at the 1PASC, Poirier had similarly mentioned that the congresses’ purpose had been for “de aquisencia as soluções practicas o solidarias a que devem propender as nossas democracias latinoamericanas.” Although the Rowe had enlarged the emphasis from a strictly South American orientation to one that would include its northern counterpart, the practical emphasis was nonetheless pervasive. It had been a common goal of all such congresses.³⁵⁷

The low value of natural philosophy can also be noted in the biographies of the respective scientists prepared for the 1PASC. Surprisingly, the actual contributions made by any given scientists did not form the prominent feature of these, but rather the positions of power and authority such scientists held. There were only two exceptions: Dr. Luis Agote, delegate from Argentina which is specifically mentioned as having discovered a new method of transfusion based on the anti-coagulatory properties of citrate of sodium, and Dr. Federico Susviela Guarch of Uruguay, who was recognized for the large number of scientific publications. Typical examples included Don Tito Linsoni of Santo Domingo or Dr. Jesus E. Monjaras of Mexico. Monjaras had been: “Miembro de la Academia

Nacional de Medicina...[miembro] de la Sociedad de Medicina Publica e Higiene Profesional de Paris, de la Sociedades de Higiene de Francia y de Espana..." and so forth. More than thirty positions and awards were mentioned for Lisoni, but the biography never even suggested what his particular scholarly contribution had been. Titles rather than scientific achievement (merit) seem to have been the basis for recognition in such congresses.³⁵⁸

Little attention was given to basic science in the proceedings. Although Luis Harperath had presented a paper during the 2LASC (1901) on "Los adelantos de la quimica moderna y los nuevos descubrimientos de Fittica", its discussion seems to have been rather brief and superficial. Similarly, Diaz Ossa complained that basic research in chemistry was seldomly undertaken in his native country. "Los estudios de Quimica pura no han tenido en el pais la extension que deberian, porque casi todos los profesionales se han dirigido mas bien a resolver los problemas de la ciencia aplicada que a cada instante se presentan." In sharp contrast to physics and chemistry, the majority of papers in "basic science" during the congress had mainly been in biology (natural history)—a rich scientific tradition in Latin America. However, even these did not address questions of principle and theory but mainly of classification.³⁵⁹

It might be argued that delegates were surprisingly rather "anti-scientific" in that they displayed very little of those values so central to science. Science to some was not a quest for the sake of nature but rather more of a spiritual and religious journey. Ducloux believed that without ethics, science could not exist, "...una ciencia sin contenido etico no es ciencia, sino una flor sin perfume, un cuerpo sin alma, menos aun, una sombra sin cuerpo. Digamosles, sin cesar, que la ciencia sin conciencia es arco maravilloso de un puente gigantessco, pero lanzado sobre el vacio..."³⁶⁰ Dr. Cobos, who spoke on the opening session of the 2LASC, was even more emphatic about the religious underpinnings of science.

Cobos lamented that despite all that had been learned about the natural world, we still understood very little of those profound metaphysical questions: what was the beginning of universe, what are the "essences" of things, what were the first causes, and so forth. "Pero tan oscura, tan insondable es para nosotros, hoy, hombres del siglo XX, la causa primera de los fenomenos de la Naturaleza, cuando decimos para explicarlos que es la divinidad del eter la que todo lo llena..." Or, regarding disease, "Sabemos que la enfermedad es nuestro enemigo, pero ¿la conocemos en absoluto y en esencia? No!" Despite the progress of the exact science, we know nothing of the universe's unity and infinity, "¿Como se desvanece desconsoladamente entonces al soplo de lo desconocio, la decantada

exactitud de las ciencias exactas!³⁶¹ The knowledge of science was but the shadow of man's ignorance.³⁶²

There is certainly a problem with this claim in that many German and U.S. scientists were also motivated by similar quasi-religious ideas, such as seeking the unity of nature (Zeilger) or proof of God's existence (Smith). Whether or not we accept the argument, however, it was certainly the case that the state of basic science had been weak in Latin America. The deficiency was lamented not only by some Latin American delegates, but by their U.S. counterparts as well.

Smith in his report of the 1PASC suggested that so much emphasis was given to the nitrate industry during the session on physics and chemistry, that little genuine work in either field was achieved. Barbour similarly commented negatively that, "The meetings of section 3 [biology] were rather disappointing...No one of the papers merited special attention, and in general in biology little original material was presented." Woodworth's report on geology showed the same tone. Curtis, who had already lived in Latin America a number of years, was even more critical. He not only pointed the deficiency out, but he attempted to explain its causes—not in a private report to the U.S. Congress but rather publicly to the Latin American delegates at the 1PASC.³⁶³

Curtis believed that the stagnation of Latin American astronomy was due to the neglect of mathematics in the educational system, as some German observers had also pointed out. However, there were historical factors at work as well. Because South American nations had started Western astronomy until the early 1800's, there were relatively few star charts available, and very few existed that preceded this date; consequently, the "knowledge of the accurate positions of the stars of the southern hemisphere is fully a century behind that of the northern hemisphere". There were also very few popular works in astronomy which helped spread interest and knowledge throughout the society, with perhaps the exception of Carlos Moesta's translation of Brunnnow's *Spherical Astronomy*. For these and other reasons, the total contributions to astronomical knowledge in the Spanish language were relatively small.³⁶⁴

Dr. Francisco Soca, of Uruguay, mentioned that Latin America's contribution had been mainly in literature rather than science, but congresses as the 3LASC were important means to stimulate local science. However, to deny this weakness was to commit the most grievous of errors. "Pois bem! por um extranho contraste, apenas a sciencia tem seguido a arte de mui longe nestas grandes jornadas da idea americana...não vae elem de algumas lustros na historia dessas democracias latino-americanas.... Dizer o contrario sem faltar ao dever de viril sinceridade que

e o cunho da força e a condição de toda obra duadoura e fecunda, compreende-se isso sem esforço.”³⁶⁵



Dolby’s model helps account for the particular character of Latin American science at the turn of the century. He describes the various factors affecting the genuine diffusion of science, which will be briefly described.

The first is the recipient’s recognition of the value of a particular idea. Obviously, if the idea appears to have no intellectual merit, the potential recipient will not pursue that idea (whatever the validity of his perception). Yet it was a factor influenced by the maturity and abstractness of a field according to Dolby; “...the truth of many new scientific ideas, particularly those that are complex or highly abstracted from experience, is not judged by a completely reliable process. Scientists have to use such partial and indirect indicators of truth as plausible argumentation and limited ranges of supporting observations.” The “age” of a field plays a similar role. Older and more mature fields have a great deal of coherence which enable them to be more easily diffused because there tend to be less conflicting “paradigms” within their realm; “a young scientific theory is not a fully coherent structure with a complete logical framework, but a rather fragmentary edifice.”

A second factor is the compatibility of social environments; linguistic, governmental, and educational differences between the potential recipient and donor nations can serve as obvious impediments. For example, if a scientific idea is strictly perceived as belonging to a particular nation, then the presence of national rivalries might inhibit the diffusion of that “foreign” idea—a point also made by Crosland and which was true of Western medicine in China during Mao’s Cultural Revolution. Even within one nation, however, linguistic differences can itself serve as a barrier to information transfer, as Trawick has showed of Japan.

Finally, the third factor is the compatibility of an idea within the recipient’s intellectual framework played a significant role in the valuing of an idea. “The ease of transmission of an innovation is affected by its compatibility with existing commitments, the advantages it is perceived as having over existing ideas and practices, the richness of its consequences, its complexity....”³⁶⁶

These general factors are rather insightful in accounting for the particular characteristics of scientific diffusion in the IPASC, particularly so when all are considered in their combined totality. One has to consider both the stage of

development of a particular science as well as the stage that a country finds itself in relative to that of its surrounding competitors.

The very process pulling Chile into modernization meant that she also would become reliant on European manpower for that modernization; the dynamics that were occurring at an industrial level had their parallels in the scientific realm as well. The turn of the century was a particularly difficult era to enter science because so many areas were undergoing a state of expansion and revolution despite claims to the contrary; man's search for the eternal meant that he would be reduced to a constant state of change. Yet because Chile lacked the scientific infrastructures to practice "normal science", she not only had to import many scientists to try to reach the leading edges, if such had ever been an immediate short term goal, but also to develop an infrastructure. Ironically, those scientists who were trained would enter an economy that had no use for them, and perhaps helps explain the preference for directly remunerative professions by such students. While there were Europeans who tried to do both work for the state and "leading edge" research, the lack of necessary infrastructures meant that most attempts would be backward before they were even begun. What had been true for them was as true for native participants. Foreign ideas were indeed incorporated, particularly so when these suited the needs of the state as was so clearly the case with the development of its nitrate industry. Yet, many of the leading revolutionary ideas as those in physics were not adopted in the sense that because there were so few native Chilean scientists to begin with—at least when judging by the local participation in the IPASCs. Obrecht and Lachaud's example are illusory in that they are more suggestive of a closer scientific proximity than was actually the case. In other words, there was too great of a social and intellectual incompatibility between Chile and the United States for there to have been a significant diffusion, and hence radical takeoff, of Chilean science. Metaphorically speaking, the road had to be built before the plane could even begin moving; it was a process that "took time", and not enough time had passed.

Perhaps quantum physics was too young and abstract to have been identified as noteworthy and significant by native Chilean "physicists", most of who had been engineers in the first place. There is even some question as to whether they would have been able to fully understand the theoretical significance of the work presented given the lack of "unified" mathematical knowledge—a trait shared by the majority of their North American counterparts. Quantum physics at the turn of the century seems to have simply been too unique to the cultural landscape of German intelligentsia to have been very widely known, and it seems unlikely that

it would have diffused anywhere else particularly so during its early origins—even despite the strong German scientific presence in Chile.

When we also consider that physics then had “little practical utility”, as Pyenson termed it, its “failure to diffuse” becomes all the more understandable in light of Latin American preferences for highly practical scholarship. If it may have not been valued because it was not understood, it was certainly not valued because its manifold applications had not yet been developed. Its diffusion was something that simply just took time. While in hindsight, W. B. Smith’s lucid and reliable account on the potential of the atom’s “unlimited energy” sound rather prophetic of what was to be, his presentation may have sounded to his audience like the words of a religious quack—especially when we consider Smith’s relatively small formal stature in the broader scientific community. Ironically, Letelier’s own explanation for the slow growth of science during the colonial period was surprisingly applicable to his era: Latin America was still too young a nation looking more for stability than progress. It was not yet ready to participate in the field because it had problems of more immediate importance.³⁶⁷

The relationship between these factors and the science of chemistry, however, led to the exact opposite outcome.

To begin with, although still a young science, physical chemistry was about twenty years older than quantum physics by the time of the IPASC. Men as Ostwald also had gone to great lengths to give the field cohesion by writing textbooks and popular articles. That the field’s intellectual perspective focused mainly with the reactions themselves also made its practical worth much more readily apparent than was with the case of pure physics—even though it was a subset of the other.³⁶⁸ Consequently, physical chemistry more readily fit into the nation’s commerce and industry than physics, even when foreigners had mainly pursued this industry. Although the science would not revolutionize Chile in the sense of leading into full industrialization nor revolutionary chemical techniques (nitrogen fixation industries), it was certainly incorporated into studies within the highly prevalent nitrate industry—an industry which was still undergoing a drastic period of expansion in 1908. Unlike physics, it had ready application to the study of *salitre*, and did not need to undergo a process of “intellectual innovation” for the ideas to be readily incorporated into research yielding immediate benefits. The importance and value of chemistry was thus ready and apparent; it more aptly fit into the preexisting social infrastructure than physics.

Yet, we may ask another question, suggested by Dolby’s framework. Were Latin American scientists even aware that a revolution in physics was underway? Obviously, it would be highly unfair to judge someone for not doing something

they didn't even know existed. We may answer that it appears that Chileans, or many other Latin Americans, were not even aware that a revolution in physics was underway throughout the congresses. There are many different reasons for this claim.

To begin, as stated previously the topic was not given much consideration at all during the session Smith attended. When Cecilio Baez gave a summary of the most important aspects of physics at the 2LASC (1901), he made no mention whatsoever of quanta but mainly of the importance of establishing meteorological observatories. While there was some work somewhat relevant to the field, it was not given any particular outstanding importance or elaborate discussion.³⁶⁹ Although we may point out Ducci's report on the recent advances in the field, we again do not get a sense of a revolution in our understanding of nature, but rather the discovery of new and unusual phenomena: x-rays, Leonard rays, etc. Again, Ducci's position as a physician may have encouraged him to more narrowly frame the significance of these events; again, their importance to him seem to have lied not so much in their theoretical implications but rather for their highly useful practical applications. If x-rays could be used to trace bones, how would other rays be usefully applied? Ducci's lecture also shows a much clearer awareness of a revolution in chemistry than in physics.

U.S. representatives at the 1PASC may have also engendered the view that there could be no revolution in physics. Michelson's powerful reputation as a Nobel Prize winner may have actually done more damage than benefit to the diffusion of science in the region because it is known that Michelson had believed physics to be nearly complete. His scientific work presented at the 1PASC aptly fit into this conception of science—the further refinement of existing work by the finding of the next decimal point. Such a public stance would have been highly detrimental in congresses becoming so highly recognized in Latin America. If the value of scientific work were partly based on its originality and novelty, then such a perception that the state of physics was of relatively finished state would have had a tremendous effect on negatively framing Latin American scientists' cognitive behavior towards physics as a whole. They would have not only been less amenable to search for these advances, but likewise for undertaking research in these leading paradigms. In this respect, pan Americanism did not aid scientific diffusion due to the atypical personality traits of a single individual.

Too much weight, however, should not be put on one man. That many Latin Americans believed themselves to have caught up to European science is also indicative that they were not fully aware of its changing frontiers. A pre-Kuhnian view of science seems to have ruled the day in that science was but the accumula-

tion of facts. Had they been more aware of the revolutionary character of such changes, perhaps local self-perception would have been of a much different sort. The relatively high self-assessment, while certainly an indication of how much had been done, likewise reveals how much ignorance existed of how much remained to be done.

Dr. Cruchaga Tocornal in 1910, for example, believed that excellent discussions in Congress, "dejo de manifiesto el gran progreso que ha alcanzado la mentalidad americana." At the 2LASC, Prof. Archevaleta said that success of first congress had been a surprise; it showed how much science had grown in Latin America. "La verdad es que pocos se imaginaban, y los de afuera menos,...[que] se hubiera venido elaborando silenciosamente una generacion de pensadores, de trabajadores en todas las ramas de los conocimientos, factores del progreso positivo." Similarly, it had been argued that Paraguay had been uncivilized, according to Aguinaga. "Se cree en el Rio de la Plata, que el Parguay se halla incommoble como la esfinge historica, petrificade en su pasado y en la desolacion que produjo la guerra." The press had done great harm in spreading this false idea. However, he believed that the congresses showed otherwise. Ironically, Argentina had also suffered the same recriminations. Herrero Ducloux responded that "No, la ciencia argentina tiene medula y es algo mas que un reflejo palido de la ciencia europea; la nueva generacion de hombres de estudio merece ser considerada en el mundo intelectual." Dr. Cornado, who called for all attendees to stand up and declare, "Ahora si que somos grandes," perhaps best encapsulates their conclusions.³⁷⁰

Although not all Latin American scientific delegates agreed with this conception of local science, these claims point to some level of disparity between such a view when compared to the latest state of European science as seen in previous chapters. Again, differences in judgment as to the merits of local science in this particular case are clearly conflicts of relativistic perception. Which point of view we take will influence our ultimate assessments of local Latin American science. While a local scientist may have seen a great deal of progress from the previous condition in which his science lay, this progress was not of a rapid enough nature relative to that of the leading scientific centers. Progress in this sense is not bounded absolutely by the internal changes of a nation, but is also bounded relatively by the international scientific competition. Ironically, for these very reasons, there were some, such as Felix Outes, who greatly opposed the entry of representatives from these scientific centers (U.S.).³⁷¹

This quasi-Darwinian competition between paradigms is also suggestive of another factor that inhibited local scientific growth. As in biology, it seems that a

new intellectual “strain” in any given population needs to have a period of isolation before it can be more widely introduced into a general population. Perhaps as Outes believed, this isolation allows the intellectual “strain” to increase in numbers, to resolve conflicts between it and previous “strains”, and to achieve some level of stable demographic plateau. Yet, it was not necessarily social isolation from the scientific metropolis but rather from rival intellectual paradigms within the peripheral nation. It appears that the “loss” of science in Latin America was more due to the prematurely broad incorporation in the congresses of countless other intellectual disciplines along with modern science rather than the entry of U.S. participants as Outes feared. Instead of giving it the “social space” needed for its internal development, the congresses actually undermined its development by swamping it with native non-scientific endeavors and perspectives. It is likely that had the congresses remained smaller and had been more selective, they would have remained more focused and oriented towards scientific activity. This oddly suggests that provincialism was tantamount to scientific advancement. The LASCs/PASCs cosmopolitan democratic tendencies meant that it was not able to consolidate a viable scientific paradigm necessary during its early stages; the scientific community was not yet cohesive and “strong” enough to open itself to the “general public”—which in this case was an aristocratic elite still entrenched by its colonial mentality. As a result, it became vulnerable to the prominence of the old paradigm, which did subsume the newer one within it as it increased in size.³⁷² It also suggests that, unknowingly, Latin Americans were also responsible for undermining their own agenda of scientific development.

We may point out that the failure or success of a field’s diffusion into a peripheral area is not necessarily entirely based on the “scientific maturity” of the region itself. In other words, it is not based on the dynamics created by the differences between scientific regions but also by intrinsic dynamics of a given scientific discipline. The state the field is in—its age, abstractness, popularity, and so forth—must also be considered as a significant factor in the process. These factors may go a long way to accounting the near absence of non-European contributions to quantum physics. That there can be hundreds if not thousands of small research paradigms means that the process of selectivity by a peripheral region is a bit more complicated than it might later seem when certain paradigms have achieved a much greater intellectual monopolization *a posteriori*. Again, the later prominence of given paradigms can all too easily be projected back into a time in history when they were but minor sub disciplines of a much more broader framework. Given the minority status of early quantum physics, it was much more difficult for foreign observers seeking to have perceived that particular paradigm’s

future importance at the time and thus to have participated in the “race.” To then assume that it should have diffused is to make an unfair demand of a historical actor that did not have our modern perspective gained only by hindsight. It is to be scientifically ethnocentric.

One should not, however, go to the opposite extreme and take this to mean that a study of the state of peripheral science is entirely an irrelevant factor in the diffusion of science. Obviously, the receptivity of a particular region to a scientific revolution or process will depend on a host of local factors—educational institutions, intellectual traditions, level of industrialization and so forth. To even suggest, for example, that a region as sub-Saharan Africa could have even participated in the quantum physics revolution is to make a ludicrous proposition having no basis whatsoever in reality. The inability to do so was not due to any suggested biological or genetic differences but simply that the Inksterian social and cultural infrastructures needed to participate in that science did not exist. There was too much to be done for it to have participated, at not only the level of information transfer but in the social structure and worldview. It was simply impossible given its state at the time; Africa was, and still is, affected by its own history. In this sense, its case is “simple” and “easy” because it is so different.³⁷³

While its simplicity can be more readily pointed out by racist observers to make equally oversimplified and unfair conclusions about African culture and society, it is useful in contextualizing the difficulties that a nation like Chile, much more culturally proximate to Europe, faced. Ironically, however, it shows that culture becomes the most prominent factor when the underlying infrastructures are at closer parity to one another; more can be attributed to it than William McNeil in his *Rise of the West* cared to recognize.³⁷⁴ Certainly one cannot use general traits as historical causes; not all historical factors or causes have the same amount of “weight” or importance to a given issue or outcome. The role of culture becomes so prominent precisely because it is so minuscule. As in a jury in a court trial, those who will have the most impact and will be most visibly remembered are not the jurors who firmly and resolutely stood on one side, but rather those whose indecisive minds swayed the uncertain case to one side or the other.³⁷⁵

Similarly, the seemingly most minor differences in cultural outlooks can have the most significant of impacts, particularly so when the social structures are relatively more nearly congruent to one another. The previously described prominence of a practical orientation towards scientific inquiry unknowingly did a great deal of injury to economic advancement in the region. As in France and Mexico, this trait so characteristic to August Comte’s philosophy undermined the

development of unforeseeable benefits of “pure” and innocent inquiry. Yet whatever its origins, whether intellectual or social, the practical tendency was so pervasive across the PASCs that it might be termed “technological scientism.”³⁷⁶

Although a great deal of formal value was placed on science, Latin America’s view of science placed a much greater emphasis on those traits more commonly associated with technology. One might point out that there was a certain amount of internal ethnocentrism in that its definition was obviously filtered through its own particular worldview. In other words, the Latin American definition of science was not the same as ours is today.³⁷⁷ Although all scientific congresses were referred to as “scientific,” most were not. As these developed, they tended to become more “professional” congresses with much more emphasis on discovering how to do things rather than the why of their existence; the emphasis on “practicality” increasingly pervaded the congresses. Although many congratulated themselves for the excellent “scientific” work done, a more careful appraisal shows that what delegates were most prominently discussing was not science per se but rather technology: the building of ports, railway facilities, and so forth. There was a much greater interest in the transfer of technology than in diffusion of science. As such, the different names of the congresses are grossly misleading. A more “appropriate” analysis of the LASCs-PASCs would be mainly within the history of technology, not within scientific history.

This contradictory and paradoxical attitude of valuing science while at the same time denigrating it seems to have been partly the result of a shift between value schemes of the Spanish colonial era and the modern North American one—an attitude somewhat inevitable during any period of cultural change.³⁷⁸ It is well known that the educational system emphasized precisely the practical profession, to the detriment of the regions general economic advancement.³⁷⁹ The unfortunate outcome is that while in Europe, the now hidden prominence of medical men eventually stimulated the creation of modern science; in Latin America their presence seems to have actually undermined the diffusion and development of this worldview into the region. It is in this sense that science was “stillborn”: the worldview was introduced into the region as an existent but non-living and dynamic entity. Science is much more than a given set of truth claims; it is a spirit of inquiry.

Conclusion



Peripheral Science Discarded?

“Chegara!... Chegara!... Chegara!”

—Dr. Francisco Soca
(Uruguay), 3LASC

To a modern scientist, the scientific work at the PASCs by Latin Americans will probably not sound too surprising. After all, the work is not all that different from what he so well knows and has studied; chemical formulas are written as they are today and the use of calculus is no different from that taught in college courses. The experiments and equations might even appear rather dull, as they reveal nothing new to him despite their somewhat puzzling assumptions.

Nonetheless, the very act of recognition by a modern hides their true value for it creates a false sense of continuity. It is perhaps harder to detect the significance of the recognizable-and-common from that which is unusual-and-exotic precisely because the latter is so different that it strikes the heart and mind. We should not be thusly deceived by our knowledge. It is the very act of recognition is here significant. The invisibility of the experience suggests that the quest then being undertaken had already been successfully achieved to some degree. So much have they become like us, that we cannot recognize them for who they actually were or had achieved. In other words, the act of recognition hides the fact that Latin America had finally entered the world of modern science by the turn of the twentieth century.

Regardless of whether they achieved anything “new” in a global sense, the methods and manner in which problems were approached reveal how much had changed. That Diaz Ossa could, in 1908, chemically understand the failure to create usable nitrogen by electrolysis meant that the intellectual tools were at his disposal to understand the mechanisms of the underlying phenomena; he could distinguish between similar physical phenomena and understand processes invisible to the naked eye. Similarly, that Damianovich could vaguely hypothesize

about to the reactions taking place paradoxically reveals the clear and distinct existence of modern science. His guesses are not based on immeasurable and intangible quantities of “phlogiston” or “miasma” but rather on definite proportions of change in nitrogen-based molecules. As guesses, they are too scientific.

We may perhaps gain a better idea of the change that had already occurred when one considers the Chilean “scientific” endeavors that had gone on in the previous century. Jose V. Lastarria, for example, sought to use science as a literary model, not a research one. Believing that the art of writing should imitate science’s, “conformidad con los hechos demostrados de un modo positivo,” he created the Academia de Bellas Letras at mid-century. Of the 77 presentations made before the Sociedad de la Ilustracion, only seven of these deal with scientific topics: five in physiology and medicine, one in botany, and another in geology. The majority had been in literary related areas. Formed by orthodox positivists in the 1870’s, the Sociedad even tried to modernize the nation through poetry contests; Maximiliano Errazuriz called for a poetry that would “stimulate interest in industry.” Science and positivism were defended before the Academia in a vivid 1876 debate by arguing that the scientific method could be applied to the study of all moral phenomena. The first true scientific society would not be formed until 1891, the “Societe Scientifique du Chili.” Even then, the foreign influence rather than the native one is clearly prevalent. Although nineteenth century Chileans may have spoken of science, properly speaking they did not conduct science. Their organizations were not scientific societies at all but remained true to their Hispanic heritage of “la tertulia.”³⁸⁰

It is thereby important to note is that science as an enterprise was being practiced rather than talked about as had been so common during much of the nineteenth century. One should not focus too much on the details of the picture and miss this general point. While certainly it was significant that particular ideas in physical chemistry had diffused, the more important point that the scientific worldview had diffused as well should not be overlooked. Latin Americans were reorienting their perspective towards nature, thus initiating what others have called in a different context a “quiet revolution.”³⁸¹ Although we have a few leading individuals, the practice of science was itself increasing throughout the society. Despite the gradual percentage “decline” of science in the PASCs, it is certainly the case that the aggregate number was increasing. More university students were exposed to these fields than ever before during the colonial period. Although small when compared to the rest of the Western world, science as an activity was increasingly taking up a percentage of Latin America’s income and

effort. No longer was it something entirely foreign and distant, but was increasingly becoming home grown.

We should similarly take a rather “broad” outlook and not quarrel too much as to the exact origins of Lachaud and Obrecht. Although certainly from France, these men lived out their lives in Chile and consequently had become part of its intellectual landscape. The German immigration to the nation also meant that, whether one wants to accept it or not, they helped shape the sum total mentality of the nation—particularly so when one considers their strong educational influence. Even when the academic disparity is pointed out between Chilean and German intellectual production in the university’s *Anales*, all of its readers were exposed to scientific work in a language they could readily understand. Although a page does not reveal the number of eyes that have lied upon it, one student or other must have been inspired to pursue science as a result. Again, even when it is correctly pointed out that Ristenpart practiced mainly for the metropole and never defined himself as “Chilean” despite the curious Spanish use of his first name, his presence helped lay the seeds of science. Nationalism should not blind an individual to the obvious contributions of foreigners in their land.

The Pan American Scientific Congresses are thus useful in showing how much had been natively achieved. The intellectual landscape showed signs of definite change, of ruptures from the past. Yet the question continually raised is why, despite this glorious start, did Latin American science not reach greater glory during the rest of our century? Why did there not emerge a Chilean Schrödinger, Hubble, or Pauling? The problem is again partly one of contextualization and not altogether entirely tied to the events *per se*.

Certainly, these questions immediately take local science and place it in a framework which is perhaps not entirely the most appropriate or fair, as pointed out by Stepan.³⁸² That Latin Americans sought to be in the world of science does not mean that the historian should unquestioningly contextualize them in that global marketplace of ideas—and perhaps even in that history. It is to wrongly judge a community by the values or experience of a small minority within that group or one external to that group however important that minority or foreign influence might be. As the recent Sydney Olympics so vividly demonstrated, because nations in Africa lack fifty-meter pools, their Olympic “swimmers” simply cannot be judged by the same standards as those of other nations with the most advanced facilities. Similarly, developing nations and their science cannot be fully judged by the same set of standards as that of more developed countries. One should also not be fooled into believing that US participation meant the acceptance of the Latin American scientist into this marketplace. There had been

non-scientific reasons for US interests in the Latin American congresses. Political foresight wisely dictated closer and more harmonious relations to the region given the emerging economic ties as well as the appearance of a new kind of war. Neighbors, after all, should not be enemies.³⁸³ Yet whatever the motive, there can be no doubt that US political participation was scientifically useful to their southern colleagues and it is likely that in the end it improved international relations between the two continents.³⁸⁴

When we do compare the two regions across all fields, we may notice that while backward in some areas—physics, chemistry, and astronomy—there were comparable levels of Latin American science to that of its northern counterpart. It is certainly the case that US fared none the better in mathematics early in the century, a well-known and studied attribute. J. W. Gibbs was one of the very few exceptions that made significant contributions to mathematically rich physics. Most US graduate students who went to Europe during this period were so mathematically ill-prepared that they were seldom able to pursue the more abstract theoretical physics, but instead tended to veer into the more general experimentalist track. Irving Langmuir, a later Nobel Prize winner, is the classic example. Curtis's assessment, however valid of Latin America, was certainly also true for his country as well. We may even point out that today most US science Ph.D.'s are not awarded to its native citizens but rather to foreign-born students. The decay of native-born US science is a well-publicized fact in drastic need of improvement.³⁸⁵

What is perhaps most surprising is that the same might even be said of German criticisms of Chilean education; they share more similarities than is usually recognized. It is rather surprising the prominence that religious leaders held in academic institutions, and the great emphasis placed on obtaining professional degrees had been equally pervasive in Germany during the nineteenth century as it had been in Latin America. The similarities are even reflected in the quasi-religious ethos of German science where the Humboltian quest for the unity of nature underlay a great number of such efforts.³⁸⁶ German criticisms of Latin American efforts, however valid of the region, hide the similarity of experiences that both nations had undergone, and suggest that German recommendations may have actually originated from its own historical experience. Latin American science was not of the same stature, but to proclaim the innate superiority of European or North American science is to deny the similarities of their historical experience.

Nonetheless, the fact remains that Latin America was "outpaced" by others throughout the twentieth century whatever the difference or similarities to other

nations in the latter nineteenth century. The frontier of science is not static in that it presents an ever-moving horizon to be continually superseded. The practice of science at the beginning of the century, as seen in the PASCs, reveals some of the problems that would continue to afflict it throughout the rest of the century. Science was not yet chosen as a profession, there was a small middle class, and there lacked a scientific entrepreneurial spirit—social factors emerging out of its Spanish Colonial past existing not only in Chile but also across all of Latin America. If Chile's prosperous nitrate economy was unable to fully stimulate physical chemistry and in turn the industrial production of nitrogen, the failing economies of many other Latin American nations certainly helped perpetuate a vicious cycle involving the reciprocal effects between scientific and economic stagnation. The foreign enclave economies existing within these regions were certainly prominent factors inhibiting local science. Chile may have also been affected by the small-country dynamics at work, making it rather typical for much of "small" Latin America.

We have also seen that the influence of the economy and culture were not quite what Mr. Sanchez would have us believe. It need not be argued that Chile's scientific delay was due to the scarcity of the resources for scientific projects as he might suggest. Although this aspect is certainly an important issue, it is to ask the wrong historical question. No matter how poor, an economy will always exist and have its own distinctive features. Consequently, this particular character of the economy has rather clear and visible effects on the character of its science, and will do so irrespective of its aggregate size. The nitrate economy clearly served as a tremendous stimulus for local science just as the cattle industry had in Argentina; as a result, the forte of native Chilean science lay not in physics but rather in chemistry. Physics, particularly when one considers that foreigners such as Obrecht and Lachaud practiced it, showed surprising degree of backwardness relative to the work in chemistry. While Diaz Ossa and others were delayed by decades, Obrecht's was in the rank of centuries. These differences can be only accounted for by the science-economy interactions found in that long strip of land bordering the Pacific.

The role of culture is a bit subtler and perhaps harder to discern than that of the economy, perhaps because in that it could also be seen within the economic realm. Ultimately, it was of an inhibitory nature. Latin Americans have long cherished the "practical" and the immediately remunerative—perhaps because of the backward non-industrial economy, positivist philosophical influence, or familial psychological dynamics. Whatever the cause might be, this practical culture ironically served as an obstacle to material and economic progress because

those intellectual enterprises not fitting into this particular cultural criterion were screened out from human activity in a process not unlike that of Darwinian natural selection. Pure physics was as a result defined as having little direct value within the Latin American cultural schema and hence did not thrive in such an environment. The physics most actively practiced and developed appears to have always been applied, never “pure.” Obrecht the astronomer was of great value as a cartographer and meteorologist; he was not primarily paid to elucidate the heavenly realm. Similarly, Lachaud only happened to be practicing theoretical physics because he probably believed that Ostwald’s techniques from physical chemistry might in turn elucidate long-standing problems. Their scientific work did not have much state or private support and was more akin to a hobby. Chileans did not know that some of the most useful sciences have been those that had been the most impractical, as John Stuart Mill once so aptly explained. Although suggested by Smith, few could have fully foreseen the tremendous power of physics.³⁸⁷ We may also note that professionally, the field of engineering co-opted its knowledge base, and in the process severely limiting the potential direct economic interactions as well as furnishing little intellectual stimulus to pure physics in return.³⁸⁸

As Dolby’s model thus suggests, modern science was unable to flourish outside its Western home because the underlying links, Inskian infrastructures, were too different. While the ideas diffused through the PASCs to Chile, their practice did not. Ristenpart’s suicide was not only a personal human tragedy but a scientific one as well. That he so identified with the goals of his profession perhaps makes him a good indicator of the social environment for science, suggesting that this environment was rather inhospitable to its growth. The Chilean government was clearly unwilling to overlook Ristenpart’s quirky personality traits for the sake of something larger than themselves: science. Obviously, they did not abide by the same value structure and generally placed science in a subordinate position not unlike that which engineering used to experience.³⁸⁹

However, a new era had begun. The PASCs had been not only its harbinger but also its midwife. Science was born from the ashes of a somber past—a past that continually pulled the intellectual orientation back to the status quo but which ultimately resulted in a new and strange amalgam. As a profession, it had emerged to be recognized by the state, even if it was hidden under the banner of more useful disciplines. As a core set of new beliefs and goals, they had been implanted amongst old and long-cherished traditions as Suarez Mujica so eloquently illustrated. The glory and sacrifice of military valor were perhaps apt values for a group continually swimming upstream seeking recognition for

intellectual, not physical, prowess and valor. A new sense of group identity and solidarity had emerged due to the Pan American Scientific Congresses, even if foreigners stood at its core. Many isolated individuals who might have given up, were now given hope that others shared his plight and that they could too recognize the merit of his efforts. It is curious note that many later eminent scientific nations initially impeded the development of scientific revolutions at the turn of the century, as had been the case with tropical medicine in England and physical chemistry in Germany.³⁹⁰ Chile's example thus suggests that it and other Latin American nations would not forever remain stagnant backwaters in the world of modern science.

Appendixes

- A. Don Eduardo Suarez Mujica's lecture about science in Latin America at IPASC.

Poirier, Eduardo, *Resena General del 4.º Congreso Científico, 1.º Pan-Americano* (Santiago de Chile: Imp. Lit. y Enc. Barcelona, 1915), 140-1.

- B. Marcel Lachaud's analysis on determining the speed of molecules.

Jose K. Ducci, ed., *Ciencias Fisicas, vol 5, Trabajos del Cuarto Congreso Científico (1.º Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910), 119-120.

- C. Wilhelm Ziegler's views of Chilean science education.

"Ideas generales sobre la enseñanza de la física en Chile." *AUC* 118 (Jan-June 1906), 1-4.

- D. Belisario Diaz Ossa's study of NaNO_3 ("salitre")

Ciencia Químicas, ed., Belisario Diaz Ossa, vol 4, *Trabajos del cuarto Congreso Científico (1.º Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910), 213-217.

APPENDIX A.

DON EDUARDO SUAREZ MUJICA ON SCIENCE AND SOVEREIGNTY.

«Excmo., Senor Presidente del Congreso, senores Delegados, senoras, senores:

Conocidas, por la publicacion de las actas del Congreso, las proporciones de la vasta y brillante labor de la jornada, medido su volumen científico, apreciada la que podria llamarse su extension en las relaciones oficiales y en las vinculaciones sociales de los pueblos del continente, solo cumple el Gobierno anadir breves palabras para fijar las proyecciones y puntualizar, por decirlo así, la solemnidad de este hecho historico, de este abrazo estrecho que han venido a darse en la capital de Chile y en nombre de la investigacion científica, los nobles emisarios del intelectualismo americano.

Cuenta America cien anos de vida propia y libre, y en este espacio de tiempo,—dilatado hasta lo inalcanzable para los individuos, fugaz como un ensueno para las naciones,—los pueblos de nuestro continente han trabajado para obtener su mas perfecta organizacion social y civil, en terminos que importan, sin duda, un esfuerzo gigantesco, profundamente honroso e incontestable fructifero.

La evolucion se ha operado, a traves de los accidentes naturales de la vida y del crecimiento organicos; pero vencidos, poco a poco, todos los obstaculos, desde las convulsiones revolucionarias hasta las asfixias de la ignorancia y de la pobreza, las nacionalidades americanas han surgido, por fin, enhiestas y vigorosas, en el mapa universal, empenadas todas ellas, en noble competencia, por subir el grado de su desenvolvimiento intelectual moral.

Y aqui es, senores, donde yo quiero insistir, con orgullo de americano, en el hecho mas grandioso y caracteristico de nuestra vida continental.

A traves de un siglo de distancia, dos revoluciones agitan la America: la revolucion de la espada, que nos dio la emancipacion politica, dejando oir los primeros vagidos de estas criaturas delicadas que constituyeron en seguida nuestras nacionalidades; y la revolucion de la ideas, que al termino del periodo secular ha venido produciendo y afianzando la otra emancipacion, aquella sin la cual de nada sirva la vida material, la emancipacion del intelecto, la emancipacion de la conciencia.

En estas dos grandes revoluciones, un noble y sublime espiritu de fraternidad ha guiado y mancomunado los esfuerzos de los heroicos obreros del patriotismo y del progreso.

Los genios militares de la America corren de un pais de la America corren de un pais al otro para auxiliarse mutuamente, en cada una de las jornadas de la grandiosa epopeya de la independencia; y, robustecido, por esta comunión generosa en el sacrificio y en la gloria, el esfuerzo colectivo va destruyendo en cada ocasión una cadena y levantando en cada etapa un pueblo independiente.

Tal fue la revolución militar.

Con la misma santa fe en los principios, con el mismo amor a la libertad, con igual culto al derecho, con el mismo sentimiento de la verdad y del bien, vemos buscarse, moverse y aliarse, un siglo más tarde, a estos otros obreros de la civilización y de la idea.

Pleyades de jefes ilustres en los ejércitos de la investigación, legiones de cruzados de la ciencia surcan los mares y transmontan las cumbres para combinar, a la sombra de la confraternidad científica, los esfuerzos no menos heroicos que tienden a asegurar la independencia,—si es posible más noble y más útil,—la independencia del cerebro.

El espectáculo de esta mutualidad de auxilio científico, de este espíritu de cooperación prodigado con tanta nobleza entre los cofrades del saber en todo el continente americano, es tan conmovedor como edificante y permite confiar en que el progreso de la America está llamando a elevarse con paso rápido y seguro a la altura de las mejores civilizaciones tradicionales.

A mí me emociona y me enorgullece, lo declaro con franqueza como hombre y como gobernante, esta visión inesperada y consoladora de todas, las eminencias americanas en viaje presuroso a Chile, desde los más remotos confines del continente, trayendo a su cabeza, como si fuera el más modesto de los hermanos, a la ilustre Delegación de la gran República del Norte, y viniendo todos, entusiastas y fervorosos, a depositar su contribución de luz en los altares de la ciencia.

Yo sigo con el pensamiento la resonancia y las derivaciones que esta llamada a tener en el comercio intelectual y material, social y político, de los pueblos del nuevo mando, una asamblea como la que acaba de celebrarse, en que la difusión de las luces, la aproximación y el conocimiento de los hombres, han de producir necesariamente, para lo futuro, el efecto de suprimir las barreras y dilatar los horizontes de la amistad sincera y de la comunidad de los intereses continentales.

Los hombres son iguales en la cuna, ha dicho Víctor Hugo; un niño vale otro niño. Lo que los diversifica, lo que los individualiza, es la conformación moral e intelectual, es el proceso evolutivo que en cada individuo realiza ese agente poderoso que se llama la educación. Y así, al paso que un ejemplar de la especie se vuelve un hombre mediante la acción educativa sabiamente dirigida, otro, en el

cual el modificativo ha sido deficiente o inconvenientemente aplicado, permanece mas o menos perdido en la envoltura impenetrable de la materia.

De ahí el esfuerzo de cada pueblo en pro del desenvolvimiento intelectual de sus hijos constituya el factor mas eficaz, mas rapido, mas irresistible de su propio engrandecimiento nacional. Recuerdo la grafica expresion del Presidente Garfield: «La grandeza de un Estado se mide por el numero de sus escuelas» porque, en verdad, senores, las escuelas son la semilla primera arrojada en el surco inculto de la masa humana ignorante y ruda, son el primer llamado que rompe el sueño intelectual y coloca al hombre sobre el riel que conduce a la region de la luz, a las cimas donde la inteligencia y el espiritu respiran a pleno pulmón el aire vivificante de la emancipacion y de la libertad.

El impulso con que los Gobiernos favorecen el mejoramiento intelectual esta eficazmente auxiliado en la epoca moderna por el extraordinario desarrollo a que han llegado el intercambio de las ideas entre los hombres de todos los paises.

Los Congresos Cientificos constituyen la manifestacion mas transparente y mas practica de esta nueva tendencia. En contacto los cerebros y los corazones, se facilita la combinacion de los esfuerzos y el control de los resultados; se puntualizan los vacios de que adolece la investigacion cientifica; se orientan las actividades en rumbos utiles y practicos, y se economizan, en fin, fuerzas vivas que de otro modo se malograrian en esteriles anhelos y tentativas.

Hasta hace pocos años estas tendencias hacia el sistema de cooperacion intelectual eran debiles, cuando no nulas, en la America latina, y estaban expresamente circunscritas por los limites etnograficos. Mientras la America anglosajona combinada ampliamente sus fuerzas en todos los ordenes de la cultura, en la generalidad de los paises de la America latina existia mas bien por el contrario, el principio de la refraccion.

Nos cabe la suerte, senores, de asistir como actores al momento historico en que las fronteras se abaten y en que la America toda, sin distincion de idiomas ni de razas, reúne a sus hombres de estudio para encarar los problemas que son comunes al continente.

Una sociedad chilena habia creado, por iniciativa, que es justo recordar, de un esclarecido hombre de ciencia europea, don Alfonso Nogues, la institucion de los Congresos Cientificos nacionales. Muy interesante y util esta institucion, no traspasaba, sin embargo, los linderos de la Republica, sino para designar algunos miembros corresponsales en los paises vecinos y para circular entre ellos sus mejores publicaciones.

La chispa, pequena en si, visible apenas fuera de Chile, tuvo su efecto, y algunos años despues, la feliz iniciativa de la Sociedad Cientifica Argentina creo,

con el éxito que al América ha venido presenciando durante más de diez años, la serie de los Congresos Científicos Americanos, de los cuales el que acaba de celebrarse en Chile ha tenido fortuna de reunir los representantes sentados oficiales y extra-oficiales de todos los países del continente.”

APPENDIX B.

MARCEL LACHAUD'S ANALYSIS ON THE SPEED OF OXYGEN MOLECULES.

1.º—ECUACION DEL CALOR ESPECIFICO

Datos: Calor específico del oxígeno, volumen constante $c = 15,1$ para 100°

Equivalente mecánico del calor 422.

Coefficiente de dilatación o presión para 1° (alfa) - 0,00367.

Incógnita: rapidez buscada,

La presión del gas sobre una pared es proporcional al número de choques y a su rapidez. Aumentando la rapidez y volviéndose doble, por ejemplo, el volumen queda constante, el libre recorrido es el mismo: la presión se cuadruplica, siendo los choques dos veces más numerosos y dos veces más fuertes. La presión ha aumentado como el cuadrado de la rapidez.

Tomemos cierto volumen de oxígeno, peso de 1 gramo, mas a $1/g$ Llevamos la temperatura de 0 a 100° , la presión aumenta, y llega a ser

$$1 + 100 (\text{alfa}) = 1,367$$

Pero el aumento de rapidez ha sido solamente como la raíz cuadrada de esta presión.

Para 1 de presión, si ella fuera x , para $p = 1,367$, a 100° es

$$x = \sqrt{1,367}$$

pero la diferencia de fuerza viva se traduce por una absorción de calor o de energía: son 15,5 pequeñas calorías por gramo a 100° .

$$\begin{aligned} \text{o } 15,5 \text{ pequeñas calorías} &= 15,5 \times (422/1000) = 6,54 \text{ kilogrammetro} \\ &= 6540 \text{ K. por kilogramo} \end{aligned}$$

correspondiendo a la diferencia de rapidez $1/2 \text{ mx}^2 \times 1,367 - 1/2 \text{ mx}^2$

$$\text{o } 1/2 \text{ mx}^2 \times 0,367 = 1/2 \times 1/9,80 \times 0,367 = 6541$$

se deduce que $x^2 = \sqrt{350.000}$ mas o menos $x = 590$ a 592 .

Sea 590 a 592.

Si el equivalente fuera 419, seria $\sqrt{346.500} = 588$

Este resultado no puede ser sino un maximum. En efecto, los movimientos de oscilacion sobre cuyo lugar hemos hablado en las generalidades, aunque debiles, no podria ser absolutamente nulos sino en el caso de las moleculas absolutamente esfericas. Estamos, pues, obligados a hacer una correccion, y no tenemos ningun medio matematico exacto de evaluacion. Sin embargo, es evidente que no podra haber una diferencia mayor de 10%, y que los valores probables corresponderan a correcciones comprendidas entre 2 y 5%. Se tendria:

Sin correccion: $Vo^2 = \sqrt{350.000} = 591$ maximum

Correccion 2%: $Vo^2 = \sqrt{343.000} = 585$

Id. 5%: $Vo^2 = \sqrt{332.000} = 577$

El valor se encontrara comprendido entre las dos rapideces

575 ^{ml} y 585

que representa la rapidez de translacion de las moleculas de oxigeno a 0°

A 100° esta rapidez seria $\sqrt{1,367}$ veces mas grande.

Para los otros gases seria inversa del peso molecular, siendo 32 este para el oxigeno....

APPENDIX C.

WILHELM ZIEGLER'S VIEWS OF CHILEAN SCIENCE EDUCATION.

Ideas Jenerales Sobre la Ensenanza de la Fisica en Chile

por el

Dr. Wilhelm Ziegler

Despues de dos anos de atenta observacion he podido formarme una idea clara del estado actual de la ensenanza de la fisica en Chile i quisiera ahora emitir mi opinion sobre sus defectos i la posibilidad de mejorarlos.

El defecto capital de que adolece esta ensenanza es, en mi sentir, la falta absoluta de conexion intima entre las distintas partes. Los profesores aislan de tal manera los diversos fenomenos que mejor podriamos designar a las clases de fisica con el nombre de «Lecciones de cosas.» Con esto el alumno se forma, como es natural una idea completamente falsa de este ramo del saber, ramo que en el ultimo decenio ha alcanzado importancia universal para todas las otras ciencias. Las leyes fisicas se aplican no solo a todas las ramas de las ciencias naturales (botanica, zoologia, quimica, jeologia i mineralojia), sino tambien a la tecnica, a la medicina i aun a al filosofia. I si nos preguntamos cual es la causa de esta posicion dominante de la fisica, debemos atribuirle unica i esclusivamente a la rigurosa exactitud que han alcanzado sus leyes por la aplicacion de las matematicas. Por consiguiente, si no queremos despojar a la fisica de un elemento indispensable para su desarrollo, i si no queremos volver a hacer de ella un ramo infructifero en la ensenanza, debemos estudiarla con el ausilio de las matematicas, en otros terminos, debemos estudiar la fisica matematicamente.

A causa de la gran multilateralidad que ha alcanzado la fisica por sus innumerables aplicaciones practicas, se ha hecho naturalmente bastante dificil la seleccion del material de ensenanza. Por consiguiente, antes de determinar este material, debemos establecer claramente desde que punto de vista debe efectuarse dicha seleccion.

¿Debe consistir la ensenanza de la fisica en el desarrollo desnudo de sus leyes, demostrando las aplicaciones de estas con aparatos de ninguna importancia en la practica? O bien, siguiendo un fin mas util a la vida, ¿deben tenerse siempre en

vista en la enseñanza las aplicaciones prácticas de la física? No necesitamos discutir la contestación a estas preguntas. El objeto de la física debe ser:

1.º Preparar a los alumnos para que puedan comprender las aplicaciones prácticas; i

2.º Hacer que con el auxilio de la ley de la conservación de la energía, ley que siempre debemos colocar en primer lugar al hacer nuestras observaciones, puedan darse cuenta de las aplicaciones útiles desde el punto de vista de la naturaleza sobre el desarrollo i desaparición del universo.

Ahora bien, si observamos la actual enseñanza, debemos confesar que en la realidad muy poco se cumple la misión arriba definida i esto se debe atribuir en primer lugar al hecho de que la mayor parte de los profesores no dominan la materia que deben enseñar. Ellos han recibido una preparación insuficiente i, a causa de los incompletos conocimientos de matemáticas que poseen, se les hace imposible conocer la más sencilla conexión interna que existe entre los fenómenos aislados. Aquí está la raíz de todo el mal i este solo se puede destruir preparando más solidamente a los profesores de la física.

Por desgracia, todavía aquí en Chile se comete el gran error de no dar a los estudios de las distintas asignaturas la importancia que les corresponde. Aun hoy hay quienes creen que una persona provista de los conocimientos recibidos de un liceo puede desempeñar el papel de profesor en cualquiera de los ramos, porque, según ellos, «es tan poco el material que para esa enseñanza se necesita, que muy bien se le puede encontrar en los libros.»

Es, pues, requisito indispensable que el profesor domine el ramo de su especialidad i esto solo lo puede conseguir con una sólida preparación en el Instituto Pedagógico. A los futuros profesores debemos primero prepararlos en su ramo i solo después que hayan alcanzado cierto grado de madurez, puede empezar la práctica pedagógica; pero también de esta debe quedar una parte en manos del profesor del ramo, a saber: la selección de la materia i su distribución en los distintos grados de la enseñanza, porque es imposible que un profesor de pedagogía que no posea conocimientos especiales de física, pueda conocer a fondo el valor de las leyes i fenómenos aislados para hacer una selección acertada del material de enseñanza. Tampoco podrá apreciar la dificultad del material para hacer una debida distribución del mismo en las diversas clases.

También en el plan de estudios del Instituto Pedagógico se ha cometido un grave error al separar por completo a la física de las matemáticas. La unión de estas dos ciencias ha traído a la física portentosos resultados en el último decenio i hoy por hoy esta unión es tan estrecha que romperla sería completamente imposible. Bien pueden entusiasmarse los matemáticos y a que pueden salir de los

secos desarrollos de sus formulas i ver cuan fructiferas i estensas aplicaciones pueden hacer con estas formulas en la practica. Por otra parte, en la fisica necesitamos indispensablemente de las matematicas, si se ha de cumplir con el fin que mas arriba he definido. ¿Como conocer, sin el auxilio de las matematicas, la importancia universal de la lei de la conservacion de la energia? ¿Como esplicamos las maquinas mas sencillas, instrumentos opticos, etc., sin las matematicas? Convengamos, pues, en que el primer requisito para preparar a nuestros jovenes profesores debe ser: «Union de las matematicas con la fisica»...

APPENDIX D.

BELISARIO DIAZ OSSA'S STUDY OF NaNO_3 ("SALITRE")

Electrolisis del Nitrato de Sodio

Por el Profesor, Belisario Diaz Ossa

INTRODUCTION

El presente estudio es el resumen de las experiencias que durante dos años he practicado con el fin de encontrar los elementos de un método que permitiese *fabricar el ácido nítrico*, partiendo del salitre de Chile, a un precio más barato que el actual sistema.

Después de algunos ensayos nos dirigimos resueltamente por la vía electrolítica, porque creemos que la industria electro-química es la industria del porvenir, ya que permite utilizar fuentes hasta casi no aprovechadas de energía y los métodos que utiliza son todos ellos sencillos y de fácil trabajo industrial.

la electrolisis de los nitratos solo se ha efectuado en dos sistemas: aprovechando la reducción electrolítica y por lo tanto reduciendo los nitratos a nitritos—sistema Müller y Weber—y la separación por electrolisis ignea con el fin de obtener la soda caústica y el ácido nítrico—procedimiento Darling.

Hasta hoy día ninguno de estos procedimientos ha dado resultados industriales, debido a causas múltiples y que no es del caso analizar.

Nosotros hemos seguido una marcha diversa: nuestros estudios se han dirigido a separar por electrolisis del nitrato de sodio, *la soda caústica* y el *ácido nítrico*, pero lo hemos hecho en disolución acuosa. Además, nuestros estudios han sido hechos teniendo en vista la aplicación en el país, en que el salitre es más barato, pues su consumo no paga impuesto, en que abundan las fuerzas de aguas y en que la minería aprovecharía, sin duda alguna, un ácido producido a un precio razonable.

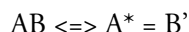
Las conclusiones a que hemos llegado nos permiten asegurar que el método propuesto se diseña y que solo faltaría para llegar a su implantación industrial, dejar a un lado las experiencias de laboratorio para hacerlas en escala semi-industrial y conocer entonces los resultados económicos.

CONSIDERACIONES GENERALES

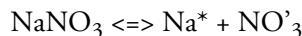
Cuando se efectua la disolucion de un cuerpo solido, tal que el NaNO_3 en el agua, se admite con Arrhenius que dicho cuerpo se descompone, o mejor, que se disocia o ioniza, es decir, se divide en dos partes que se denominan iones y que son series de atomos o corpusculos dotados de cargas electricas poderosas iguales y de signos contrarios.

Los iones se clasifican, segun sus cargas electricas, en iones positivos y negativos y se denominan cation y anion segun se dirijan al catodo o al anodo.

De tal modo que el NaNO_3 cuando se ioniza, se divide en el Na^+ que es el cation y el NO_3^- que es el anion y que se escriben de la manera vista segun convenio internacional. Pero cuando la ionizacion no es completa en el seno del liquido acuoso, existen tres clases de radicales diferentes: aniones, cationes y moleculas neutras existiendo entre ellos un equilibrio que depende en particular de la disolucion y de la temperatura.



o sea en este caso



Segun esto los iones los podemos clasificar en dos series distintas: los iones actuales que son los que existen en el instante considerado y los iones virtuales que existen unidos en la molecula neutra, y por lo tanto podemos aplicar a la disolucion la ley de las masas y del equilibrio quimico, y tendremos:

$$C_1 C_2 = K C_n$$

o simplemente

$$(C_1/C_2)/C_n = \text{Constante}$$

en que

C_1 representa la concentracion del anion

C_2 » » cation

C_n » » de la molecula neutra.

Pero como el numero de aniones y cationes es el mismo en cada caso, tendremos:

$$(C_1/i)/C_n = \text{Constante'}$$

en que

C_1 representa la concentracion del anion
 C_n » » » de la molecula neutra.

Son los iones los que conducen la electricidad de un lado a otro en un liquido electrolizable, de tal manera que la mayor o menor conductibilidad de un electrolito dependera de la cantidad de iones actuales existentes en el liquido y de cuando todas las moleculas se encuentran disociadas, ionizadas, es decir, cuando los iones virtuales hayan pasado a ser actuales, se tendra la mayor conductibilidad de la disolucion que se denomina en electroquimica: conductibilidad equivalente, maxima o limite.

La conductibilidad equivalente limite es igual, por lo tanto, a la suma de las movilidades equivalentes de los iones, o sea,

$$\lambda_{\infty} = l_a + l_o$$

en que l_a representa la movilidad del anion y l_o la movilidad del cation. A continuacion damos un cuadro de algunas movilidades necesarias en este estudio tomadas a la temperatura 18° C.

H*	329,8
Na*	43,55
OH'	174
NO ₃	61,78

Siendo los iones los que conducen la electricidad en el seno de la disolucion, al perder la carga electrica de que estan dotados se transforman en particulas materiales con las propiedades que les conocemos. De tal modo que durante la electrolisis existen dos corrientes de iones: unos que se dirigen a un polo, los cationes al catodo, y otros a otro, los aniones al anodo; pero la experiencia demuestra que ambos no marchan con la misma velocidad, que unos son mas veloces que los otros, esta velocidad relativa de los iones, numeros de transportes o numeros de

Hittorf (1851) desempeñan un papel muy importante a la vez que perjudicial en la electrolisis.

Los numeros de transporte se pueden determinar experimentalmente por el conocido medio de la electrolisis con un plano intermedio invariable, valiendose para ello del aparato propuesto por Noyes (1903) o el de Nernst y Loeb (1888) primitivo o modificado por Ostwald (1902).

Tambien se le puede calcular partiendo de la formula:

$$\lambda_{\infty} = l_a + l_o$$

pues si llamamos u la velocidad absoluta del anion y v la del cation tendremos la expresion:

$$n/v = l_a/l_o = n/1-n$$

en que n y $1-n$ representan las velocidades relativas y donde:

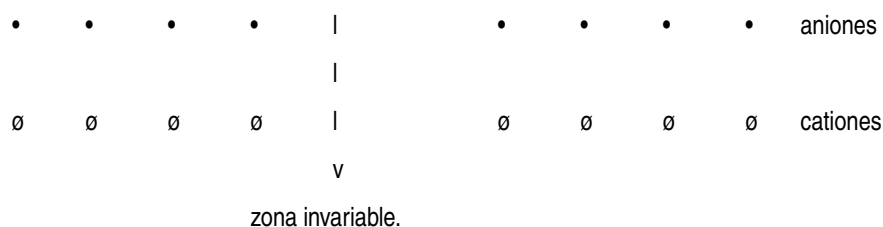
$$1-n = (l_o/l_a + l_o) \quad y \quad n = (l_a/(l_a + l_o))$$

Las medidas efectuadas por nosotros para el NaNO_3 son sumamente concordantes con las deducidas por el calculo, y son las que se dan en el cuadro adjunto:

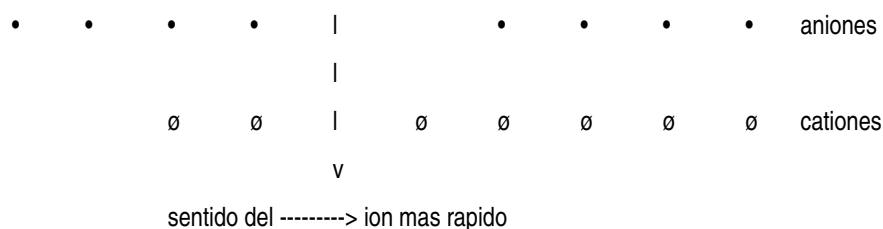
	Vel. rel. del cation $1-n$	Vel. rel. del anion n
NaNO_3	0,41	0,59
NaOH	0,20	0,80
HNO_3	0,84	0,16
H_2O	0,65	0,35

Los numeros de transporte o velocidades relativas cambian con la temperatura y tienden hacia el limite 0,6; en decir, a tener los iones la misma velocidad. Cuando la velocidad relativa de los iones es la misma, el liquido se empobrece igualmente de la sal que se electroliza; pero cuando la velocidad de los iones es diferente, la solucion se empobrece desigualmente y parece, por lo tanto, enriquecerse en sal del lado ion mas rapido y empobrece de lado del ion menos rapido.

En el esquema podran verse mas claro estas conclusiones:



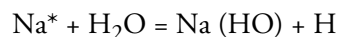
Despues de hacer pasar la corriente durante un tiempo igual a tres Faraday o sea 3 veces 96,537 coulombs, como las velocidades de los iones son diferentes tendremos:



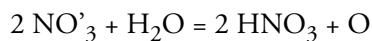
se habran separado tres equivalentes por lado en cada electrodo, pero en un lado solo tendremos dos aniones y dos cationes y del otro lado cinco cationes con los aniones correspondientes, luego la solucion se empobrece en sal del lado del ion menos rapido.

Los numeros de transporte tienen tambien otra intervencion y que hemos llamado perjudicial: cuando se efectua la electrolisis del nitrato de sodio con electrodos inatacables y en disolucion acuosa, suceden las reacciones siguientes:

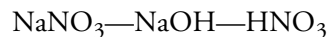
El ion Na^* se descarga en el catodo y con el agua produce la reaccion secundaria:



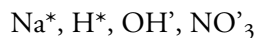
dando hidrato de sodio o hidrogeno que se desprende. En el anodo o polo positivo se libera el ion NO_3' produciendose la reaccion secundaria



en una palabra, despues de cierto tiempo de pasar la corriente existiran los siguientes cuerpos, siempre que la zona invariable no se destruya:

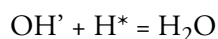


en otros terminos existiran simultaneamente los iones



todos los que contribuiran a la conductibilidad del electrolito. Rodeando el polo negativo o catodo tendremos en especial de los iones OH' que se dirigan hacia el polo positivo o anodo con el fin de descargarse; por el contrario, rodeando el polo positivo se encuentran los iones H^* que se dirigan hacia el catodo de tal modo que una parte del NaOH formado en el polo negativo se perdera, pues los iones OH' marcharan hacia el polo contrario y otra parte al HNO_3 formado le sucedera igual cosa; estas perdidas tanto en hidrato como en el acido seran proporcionales a la velocidades relativas de los iones OH' y H^* respecto a los demas iones y a concentracion alcanzada en acido y en hidrato. Este es el caso mas favorable y mas tarde veremos como se complica; por el fenomeno de Hittorf hay siempre una perdida en los rendimientos tanto anodicos como catodicos imposible de evitar.

Ademas la marcha en sentido opuesto a los iones OH' y H^* produce otros efectos cuyas consecuencias esplicaremos mas tarde; bastenos decir por ahora que ambos iones se unen y perdiendo sus cargas electricas se convierten en agua



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Endnotes

1. Alan Sokal and Jean Brickmont, *Fashionable Nonsense: Postmodern Intellectuals' Abuse of Science* (New York: Picador, 1998); Paul R. Gross and Norman Levitt, *Higher Superstition: The Academic Left and its Quarrels with Science* (Baltimore: Johns Hopkins University Press, 1994).
2. Henry Wells, *The Modernization of Puerto Rico: A Political Study of Changing Values and Institutions* (Cambridge, M.A.: Harvard University Press, 1969); George M. Foster, *Traditional Cultures and the Impact of Technological Change* (New York: Harper and Brothers, 1962); Glen Caudill Dealy *The Latin Americans: Spirit and Ethos* (Boulder: Westview Press, 1992); Carmen de Ruiz Feschler and Mercedes Trelles, eds. *Los tesoros de la pintura puertorriquena* (San Juan: Museo de Arte de Puerto Rico, 2000).
3. Francis H. Nichols, "Cuban Character," *The Outlook* 62, 13 (July 29, 1898), 707-713; George Kennan, "The Regeneration of Cuba," *The Outlook* 61, 9 (March 4, 1899), 497-501; George Kennan, "Cuban Character," *The Outlook*, 63, 17 (Dec 23, 1899), 959-965, 63, 18 (Dec 30, 1899), 1016-1022; Thomas Barbour, *A Naturalist in Cuba* (Boston: Little, Brown, & Co, 1945), 11-13, passim; E. O. Wilson, *Naturalist* (Washington D.C.: Island Press, 1994), passim.
4. Some argue that the lack of recognition is due to a certain prejudice against the work of Latin American scientists. Latin American journals are seldom read in the US, and databases do not generally incorporate these journals as well. Manuel Patarrollo attacked the international scientific community for not giving more credit to his work on malaria.
5. T. Braun, W. Gläznel, "A Topographical Approach to World Publication Output and Performance in the Sciences, 1981-1985," *Scientometrics* 19,3-4 (1990), 159-165; A Schubert and T. Braun, "International Collaboration in the Sciences, 1981-1985" *Scientometrics* 19, 1-2 (1990), 3-10; A. Schubert, W. Gläznel, T. Braun, "Scientometric Data files. A Comprehensive set of Indicators on 2649 Journals and 96 countries in All

- Major Science Fields and Subfields, 1981-1985," *Scientometrics*, 16, 1-6 (1989), 3-478.
6. Charles A. Hale, *The Transformation of Liberalism in Nineteenth Century Mexico* (Princeton: Princeton University Press, 1989); David J. Hess, *Spirits and Scientists: Spiritism, Ideology, and Brazilian Culture* (University Park: Pennsylvania State University Press, 1981); Stephen Lockhart Fogg, "Positivism in Chile and its Impact on Education, Development, and Economic Thought, 1870-1891." PhD. thesis, New York University, 1978; Ralph Lee Woodward, ed., *Positivism in Latin America, 1850-1900: Are Order and Progress Reconcilable?* (Lexington, MA: Heath Pub., 1971).
 7. Chris Freeman and Luc Soete, *The Economics of Industrial Innovation*, third edition (Cambridge, MA: MIT Press, 1999); H. Floris Cohen, *The Scientific Revolution: A Historiographical Inquiry* (Chicago: University of Chicago Press, 1994)
 8. This is perhaps not a fair statement in that Darwin was obviously influenced by his British philosophical and scientific background, different from that in Latin America. However, it is fair in that it seems to aptly characterize the general atmosphere of the region's natural history in this author's opinion. Nature's beauty was to be feared and admired, but not necessarily to be understood.
 9. Manuel Fernandez Alvarez, *Copernico y su Huella en la Salamanca del Barroco* (Salamanca: Universidad de Salamanca, 1974); David Goodman, "The Scientific Revolution in Spain and Portugal," in *The Scientific Revolution in National Context*, ed. Roy Porter and Mikulás Teich (Cambridge: Cambridge University Press, 1992), 158-177; Kostas Gavroglu, ed, *The Sciences in the European Periphery During the Enlightenment* (Dordrecht: Kluwer Academic Publishers, 1999); T. Glick "Science and Independence in Latin America," *HAHR* 71 (1991):307-334; Frank Safford, *The Ideal of the Practical: Colombia's Struggle to form a Technical Elite* (Austin: University of Texas Press, 1976); Simon Schwartzman, *A Space for Science: The Development of the Scientific Community in Brazil* (University Park, Pennsylvania: Penn. State University Press, 1991). Victor Wolfgang Von Hagen, *South America Called Them: Explorations of the Great Naturalists: La Condamine, Humboldt, Darwin, Spruce* (New York: A. A. Knopf, 1945); Iris H. W. Engstrand, *Spanish Scientists in the New World: The Eighteenth Century Expeditions* (Seattle: University of Washington Press, 1981); Arthur Robert Steele, *Flowers for the King: The Expedition of*

Ruiz and Pavon and the Flora of Peru (Durham, NC: Duke University Press, 1964); Douglas Botting *Humboldt and the Cosmos* (NY: Harper & Row Pub., 1973); Robert S. Hopkins, *Darwin's South America* (New York: John Day Co., 1969); Charles Darwin, *The Voyage of the Beagle* (New York: Batnam, 1972).

10. Lincoln Gordon, *A New Deal for Latin America* (Cambridge: Harvard University Press, 1963; ed. John C. Dreier, ed., *The Alliance for Progress: Problems and Perspectives* (Baltimore: Johns Hopkins University Press, 1962); Jonathan B. Bingham, *Shirt Sleeve Diplomacy: Point Four in Action* (New York: Books for Libraries Press, 1954); Merle Curti and Kendall Birr, *Prelude to Point Four: American Technical Missions Overseas, 1830-1938* (Madison: University of Wisconsin Press, 1954).
11. Imre Lakatos, *The Methodology of Scientific Research Programs* (Cambridge: Cambridge University Press, 1978); I. Lakatos and A. Musgrave, eds., *Criticism and the Growth of Knowledge* (Cambridge: Cambridge University Press, 1970).
12. If many of the existing works of Latin American science deal with natural history, this book forms a departure from that trend. Although important, they seldom reveal the dynamic changes of Latin American thought. Much like their subjects, they are all too often massive collections of data that have relatively little intellectual dynamism or broader social meaning; they stand dangerously close to antiquarianism. I certainly do not mean to denigrate those works about 'scientists' doing natural history—a feature so prevalent during the Spanish colonial period. Rather, the point is that they tend rather to fail to contextualize local learning in its broader scientific schema. The same story is repeated over with minor changes and without any significant contributions by the book as to broader scientific advancements. The 'adventure' in science does not consist in the physical movement and experiences of the scientist, but rather of the intellectual changes going on inside his/her head. There is usually little of that challenge, that sense of wonder and pace of discovery that so commonly characterizes other scientific histories. Perhaps this has to do with the fact that such changes were actually relatively slow, and that too much scientific work consisted in such slow prodding. Certainly, however, the historian need not be as constricted by his evidence. Sadly, works in non-biological area as Pyenson's which one would expect to have been more 'dynamic' and consequently to have contributed more to our understanding of local

science, are all too similar to these. Certainly, the contextualization varied from author to author. Lewis Pyenson, *Cultural Imperialism and Exact Sciences: German Expansion Overseas, 1900-1930* (New York: Peter Lang, 1985); For an interesting depiction of changes in historical methodologies, see Joyce Appleby, Lynn Hunt, and Margaret Jacob, *Telling the Truth About History* (NY: W. W. Norton, 1994).

13. Safford, Introduction.
14. *Daily Bulletin*, December 28, 1915.
15. Attending U.S. associations included: American Political Science Association, American Historical Association, American Economic Association, American Anthropological Association, American Folk-lore Society, Archeological Institute of America, American Sociological Society, American Civic Association, American Association for Labor Legislation, American Statistical Association, American Society for the Judicial Settlement of International Disputes, American Society for International Law, etc.
Daily Bulletin/Boletín Diario, Dec. 28, 1915, 4. Unless otherwise indicated, *Daily Bulletin* refers to English version of the newspaper. The textual content of two language versions was nearly identical, even if the photographs and the captions included in each greatly varied.
16. 2PASC, *Proceedings of The Second Pan American Scientific Congress, Washington, U.S.A. December 27, 1915 to January 8, 1916*, vols. 1-11. (Washington: U.S. GPO, 1917).
17. Frederick Davenport, "A Great Gathering of The Experts," *The Outlook*, 112 (Jan. 19, 1916), 130.
18. *Daily Bulletin/Boletín Diario*, Dec 28, 1915.
19. "2PASC," *Bulletin of the Pan American Union*, 760.
20. *Daily Bulletin/Boletín Diario*, Jan 8, 1916.
21. Ernesto Quesada, *El Nuevo PanAmericanismo y El Congreso Científico de Washington* (Buenos Aires: Talleres Gráficos del Ministerio de Agricultura de la Nación, 1916), Appendix.
22. It had been designed by Sally James Farnham, a 'well-known N.Y. sculptress'. *Daily Bulletin/Boletín Diario*, Jan. 9, 1916, 5; "2PASC," *Bulletin of the Pan American Union*, 776-8; *Daily Bulletin/Boletín Diario*, Spanish version, Jan. 4, 1916, 2; *Daily Bulletin/Boletín Diario*, Dec. 31, 1915, 5;

- Daily Bulletin/Boletín Diario*, Dec. 30, 1915, 1; *Daily Bulletin/Boletín Diario*, Jan. 5, 1916, 1.
23. Alberto Gutierrez, *Informe presentado al Ministerio de Relaciones Exteriores de Bolivia* (La Paz: Imprenta Velarde, 1916), 14-15.
 24. See *Conferencias Internacionales Americanas, 1889-1936* (Washington: Dotacion Carnegie Para la Paz internacional, 1938); *The International Conferences of American States, First Supplement, 1933-1940* (Washington DC: Carnegie Endowment for International Peace, 1940).
 25. In more recent times, consult the following: *Special Issue Containing papers presented at the Seventh Latin American Symposium on Surface Science. LA Symposium on Surface physics., 7th, 1992, Bariloche, Argentina* (Bristol, England: Institute of Physics Building, 1993); *Latin-American Inorganic Chemistry Meeting, Santiago de Compostela, Spain, 13-17 Sept 1993: Collected Abstracts* (Santiago de Compostela: Universidad de Santiago de Compostela, 1993); *Meeting of the Southern Hemisphere on Mineral Technology: 4th, 1994, Concepcion, Chile. Advances en tecnologia mineral* (Concepcion: Universidad de Concepcion, 1994) ; *Gold Extraction: fundamentals & practice* (Belo Horizonte: Minas Gerais, Brazil: Asociacao Brasileira de Tecnologia Mineral, 1998); *3rd Meeting of Southern hemisphere on Mineral Technology* (Belo Horizonte: Minas Gerais, Brazil: Asociacao Brasileira de Tecnologia Mineral, 1998) ; *Primera Reunion Astronomical Regional LatinoAmericana, 16-21 June, 1978. Latin American Regional Astronomy Meeting* (Santiago de Chile: Observatorio Astronomico Nacional, 1979) ; *Memorias de la Septima Reunion Regional LatinoAmericana de Astronomia, Vina del Mar, 2-6 Nov, 1992* (Mexico DF: Universidad Nacional Autonoma de Mexico, 1993); *Proceedings of the Symposium on Pan-American Collaboration in Experimental Physics. Symposium, 3rd. Oct 19-23 1987, Rio de Janeiro* (Singapore: World Scientific, 1987); *30th Annual Meeting, Canadian Federation of Biological Sciences: Joint Meeting with the Pan-American Association of Biochemical Sciences. Winnipeg, Manitoba; June 22-26, 1987* (Canada: The Federation of Biochemical Sciences, 1987); *Latin-American Workshop on Plasma Physics and Controlled Nuclear Fusion Research, Cambuquira, Minas Gerais, Brazil, Feb. 8-12, 1982* (Rio de Janeiro: Sociedad Brasileira de Fisica, 1982); *Summaries of the First Latin American Meeting on Relativity and Gravitation. Universidad de la Republica de Montevideo* (Rio de Janeiro: Sociedad Brasileira de Fisica, 1972); *Latin American School of Physics, 30th ELAF.*

Group theory and its applications, Mexico City, July-August 1995. Latin American School of Physics (Woodbury, New York: AIP. Press, 1996); *Latin American Meeting on High-Energy Physics/Encuentro Latino Americano de Fisica de Alta Energia, Universidad Federico de Santa Maria, Valparaiso Chile, 10-16 Dec, 1987* (Valparaiso: Unviersidad Tecnica, Federal, 1987).

26. Few secondary works exist. Francesca Miller, "The International Relations of Women of the Americas, 1890-1928," *The Americas* 43, 2 (Oct 1986), 171-183 ; Francisco Sagasti and Alejandra Pavez, "Ciencia y tecnologia en America Latina a principios del siglo XX: Primer congreso cientifico panamericano." *Quipu* 6, 2 (May-Aug 1989), 189-216.
27. *Daily Bulletin*, January 5, 1916.
28. Minutes for meetings between May 21 1907 through June 4, 1908 can be found in 4o Congreso Cientifico, 1ro Pan Americano, *2do Boletin: Trabajos Preparatorios Hata el 30 de Junio de 1908* (Santiago de Chile: Imp. Litog. Encd. "La Ilustracion", 1908), 1-51.
29. Septimo Congreso Cientifico Americano, *General Information on the Seventh American Scientific Congress* (Mexico D. F.: Talleres Graficos de la Nacion, 1932); Secretaria de Relaciones Exteriores, *Acta Final del Septimo Congreso Cientifico Americano* (Mexico D. F.: Imprenta de la Secretaria de Relaciones Exteriores, 1936); *Eighth American Scientific Congress, Proceedings of the Eighth American Scientific Congress, held in Washington May 10-18, 1940*. 11 vols. (Washington D.C.: Department of State, 1942).
30. "The Second Pan American Scientific Congress," *BPAU*, 788.
31. Murillo, Adolfo. *Trabajos presentados al V congreso cientifico general Chileno de 1898* (Santiago de Chile: Imprenta Cervantes, 1898); Eduardo de la Barra, *Ortografia fonetica; IV congreso cientifico de Chile* (Santiago de Chile: Establecimiento Poligrafico Roma, 1897.). Allusions to local scientific congresses also found in 3LASC. See 3LASC, *1o Boletim: Trabalhos Preparatorios ate 31 de dezembro de 1903, Terceira Reunião do Congresso Cientifico Latino-Americano* (Rio de Janeiro: Imprenta Nacional, 1904), 1. According to some, the Chilean national scientific congresses served as model for Argentinian LASC's; obvious some competition going on here between Chile and Argentina. Delegacion Chilena, *Chile ante el Congreso Cietnifico Internacional Americano de Buenos Aires; Informes I Monografias; Congreso Cientifico Internacional Americano, Buenos Aires, July 1910*, (San-

tiago de Chile: Imprenta Universitaria, 1911), 62. For Argentinean origins of LASCs, see Dr. Emilio R Conio, "Primer Congreso Científico Latino Americano," in *Anales de la Sociedad Científica Argentina* 83 (1917): 254-261; "Congreso Científico Latino-Americano," *Anales de la Sociedad Científica, Argentina* 45 (1898), 369-389. Almost all documents pertaining to the PASCs give credit to Argentinian delegates founders. 1PASC, *Segundo Boletín*, iii.

32. Elias Tribulas, *Siglo XIX*, vol. 5, *Historia de la Ciencia en Mexico* (Mexico D.F.: Fondo de Cultura Economica, 1992), 427-426.
33. Cárlos Moesta, director of Chilean national observatory, attended the international scientific congress at Leipzig in 1865. At the congress, apparently the importance of his work had been recognized. *Chile ante el Congreso Científico*, 32; Marco Arturo Moreno Corral, *Odisea 1874 o el primer viaje internacional de científicos Mexicanos* (Mexico, D.F.: Fondo de Cultura Economica, 1995).
34. "Congreso Científico Latino-Americano" *Anales*, 369-389.
35. Poirier, *Resena General*, 2-3. The total attendees mentioned by him for last congress, in which he was its Secretary General, seems a bit inflated. Other sources suggested a smaller number.
36. A random sampling of the listing shows that predominant majority of participants were from Uruguay, especially Montevideo. Details are as follow (A-Argentina, C-Chile, U-Uruguay, T-total; first number alludes to number of participants, and the other its percentage in page): Page 1-25 T; U (14-56%); A (6; 24%) C (3; 12%); page 2-40 T ; U (27; 67%); A (9; 23%); C (2; 5%); page 3-43 T; U (31; 72%); A (5, 11%); C (3;7%); page 4-41 T; U (27; 66%); A (5; 12%); Brazil (1; 2%); page 5-41 T; U (33; 77%); A (4; 7%); C (2; 5%); page 6-45 T; U (34; 76%); A (4; 8%); C (3; 7%); page 7-38 T; U (25; 66%); A (8; 21%); C (1; 5%); page 8-26 T; U (19; 73%); A (5; 19%); C (1; 4%). Segunda Reunion del Congreso Científico Latino Americano (Montevideo), *Parte I-Organizacion y Resultados Generales del Congreso* (Montevideo: Tip y Enc. Libro Ingles, 1901), 21-28.
37. There were 95 papers in the social sciences. The distribution of the total 209 papers are as follow: exact sciences-10; "ciencias fisico-quimicas naturales"-21; engineering-13; agronomy and "zootenica"-11; medicine-69; social sciences: 23; "ciencias pedagogicas" and anthropology-62. The

rough distribution is: basic science-10%; app science-44%; soc science-45%. *Ibid.*, 41-50

38. Paul S. Reinsch, "The First Pan American Scientific Congress' *The Independent* 66 (Feb. 18, 1909), 370-373.

For 3LASC, the country distribution was as follows: Individuals Argentina 74; Bolivia 5; Brazil 474; Chile 13; Colombia 7; Costa Rica 3; Cuba 2; El Salvador 1; Ecuador 4; Guatemala 3; Haiti 1; Honduras 2; Mexico 5; Nicaragua 2; Paraguay 8; Peru 11; Uruguay 80; Venezuela 2; total 697. Brazil had 68% of the delegates while Uruguay only had 11%. Institutions Argentina-5; Brazil 44; Chile 4; Haiti 1; Paraguay 4; Uruguay 25; total 83. Similar pattern is repeated; Brazil had 63% of institutions, followed by Uruguay's 30%. Dr. Antonio de Paula Freitas, ed., *Relatorio Geral, Terceira Reunião do Congresso Cientifico Latino-Americano* (Rio de Janeiro: Imprensa Nacional, 1906), 125-6.

For 4LASC/1PASC, number of delegates were as follow: Total : 1,899; 1,119 Chile, 377 Argentina, 63 Peru, 61 Brazil, 55 U.S., 52 Bolivia, 32 Mexico, 31 Uruguay, 19 Guatemala, 7 Columbia, 5 Cuba, 5 Ecaudor, 4 Haiti, 4 Panama, 4 Paraguay, 2 Honduras, 2 El Salvador, 2 Santo Domingo, 1 Nicaragua, 1 Venezuela. Poirier, Resena General, 2-3; "First Pan-American Scientific Congress," *Bulletin of the International Bureau of the American Republics*, 28 (January-June 1909), 585-586; Gutierrez, 31.

With regard to scientific distribution of papers, numbers are as follow. For 3LASC, out of a total of 120 papers, 53 were in applied science (44%) while social sciences had 45 (36%) ; natural science only had 22 (18%). Freitas, ed., *Relatorio Geral*, 127-139. For 4LASC/1PASC, the numbers are as follow: math-15; physical and chemical sciences-50; anthropology and biology:-40; engineering-31; medicine-83; legal sciences-13; social sciences-86; pedagogical sciences-81; agronomy and zootecncis-48. Poirier, *Resena General*, 251-267.

39. Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (Cambridge, MA: Harvard University Press, 1987), 163. The history of quantum mechanics and the "energeticist revolution" has been so widely studied, that secondary works will not be mentioned unless specifically quoted.
40. The actual growth was: 1LASC-23; 2LASC-21; 3LASC-53; 1PASC-65; 2PASC-68.

41. Initial subsections for IPASC were: pure and applied math; physical science; natural sciences; medical and hygienic sciences; juridical, political, and social sciences; Pedagogical ; Agronomy and zootechnology. The issue was discussed in second session of June 6, 1907 and in 6th Session on July 25, 1907 of organizing committee, but had not reached any conclusions. By the 13th session (Oct. 12, 1907) it decided to add more humanities sections: anthropology, and divide juridical and social sciences into two separate sections. IPASC, *2do Boletín: Trabajos*, 6, 10, 20-1. 2LASC had 9 sections in total; with many social sciences included: ciencias exactas; ciencias físico-químicas; ciencias naturales; ingeniería; agronomía y zootécnica; ciencias médicas; ciencias sociales y políticas; ciencias pedagógicas; ciencias antropológicas. This was much more of a rational organization than divisions that followed, as when IPASC combined natural sciences and anthropology, should have left it the way it was. 2LASC, *Organización y Resultados*, 12.
42. Reinsch, *Independent*, 372; Gutierrez, 1; "Second Pan American Scientific Congress," *Scientific American*, 114 (April 1916), 344; Prior to that, however, *The Outlook* had even proclaimed that "perhaps the greatest achievement of the congress [1LASC] was to give to 'Pan-Americanism' a meaning and purpose more definite than it has ever possessed before." Quoted in "First Pan-American Scientific Congress," *Bulletin of the International Bureau*, 325.
43. Andre Gunder Frank, ed. *Capitalism and Underdevelopment in Latin America: Historical Studies of Chile and Brazil* (New York: Monthly Review Press, 1969); Theotonio Dos Santos, "The Structure of Dependence," *American Economic Review* 38 (August 1973): 424-438; *Latin America since 1930, Part 1: Economy and Society* (Cambridge: Cambridge University Press, 1984), vol. 6., *Cambridge History of Latin America*, ed. Leslie Bethell.
44. Dr. Thomas H Norton, of the Department of Commerce, and Dr. A. S. Cushman, director Institute for Industrial Research, both said that W.W.I was not a war of bankers as was commonly accused, but rather of chemists. Nitrate is both used for agriculture (nitrogen fixation in soil) and explosives (nitric acid). That Germany was able to discover a way of extracting this from different sources, thus making her self-reliant, in contrast to the U.S. (and thus encouraging aggressive actions.) Dr. A. S. Cushman said that the only thing that prevented war was that chemists

were not ready four years ago. Two Americans had invented process of extracting nitrogen from air, but were unable to further develop it because of a shortage of capital. *Daily Bulletin/Boletín Diario*, Dec 31, 1915, 4.

45. Leo S. Rowe, "The Pan-American Scientific Congress," *The American Review of Reviews* 39 (May 1909), 598. This would not be unlike the criticisms made of Roman Catholic rituals as confession—North Americans turned South America's weapons on itself. This was not unlike the criticism made of Roman Catholic's confession ritual by Francisco Bilbao. By opening one's conscience to the priest, one became amenable to intellectual manipulation. (see Bilbao's critiques).
46. At the plenary session held on Jan 4, 15 of 18 countries voted for the selection of Washington DC; opposing 3 had voted for Lima, Peru. The opposing three later changed minds, and allowed it to be moved to U.S.. William Shepherd, "The Scientific Congress at Santiago," in *Columbia University Quarterly* (June 1909), 334. Also note that agreements seem to have occurred behind doors. During the last session of 2LASC Dr. Wernicke asked if anybody wanted to read a resolution. Yet when 2 delegates, Sr. Paz Soldan and Sr. Pezzurno, tried to read one they were twice denied by Dr. Wernicke apparently because there was not enough time to read every section's resolutions. Mr. Pezzurno had the last say. "Pero el señor Presidente nos invito a hacer algunas indicaciones que ahora resulta que no se pueden hacer. Es, pues, inútil que se nos ofrezca que proponagamos alguna cosa." 2LASC, *Organización y resultados*, 196.
47. For example, 1LASC was held in April 1898, 2LASC in March 1901, 3LASC in Aug 1905, and the 1ASC (Buenos Aires) in July 1910. By contrast, the first two PASC's were held in December, 1908, 1915 respectively, and other ASCs, for example the 7th and 3rd, in the months of February and December respectively.
48. *Daily Bulletin/Boletín Diario*, Dec. 28, 1915-Jan. 9, 1916, passim.
49. "First Pan-American Scientific Congress," *Bulletin of the International Bureau*, 590; Willaim Spence Robertson, *Hispanic-American Relations with the United States*, (New York: Oxford University Press, 1960; reprint 1923), 406.
50. *Daily Bulletin/Boletín Diario*, Jan 5, 1916, 6; Riensch, *Independent*, 372; Phillip C. Jessup, *Elihu Root*, 2 vols. (New York: Dodd, Mead and Co.,

- 1938); Richard William Leopold, *Elihu Root and the Conservative Tradition* (Boston: Little, Brown & Co. 1954); Shepherd, 379,383.
51. Rowe, ARR, 600; 1PASC, *Primer Boletin: Bases, Programa, y Cuestionario General, 2a ed.*(Santiago de Chile: Impr., Lit. La Ilustracion, 1908), 70-1; 1PASC, *Segundo Boletin: Trabajos Preparatorios Hasta el 30 de Junio de 1908* (Santiago de Chile: Imp. Litog. Encd. La Ilustracion, 1908), 100-102. Detailed notes of organizing committee's meetings were included in the *Segundo Boletin*; it should be noted that previous committees had not published their minutes. Sylvester Baxter, "The Western World in Conference: Rio de Janeiro and the Conference at the Palace Monore," in *The Outlook* (Sept. 22, 1905), 188; "The American Delegates to the Pan-American Congress" *The Outlook* (April 28, 1906), 981. It is curious to note that 1906 PAC was also attended by Tulio Larrinaga, PR Resident Commissioner in the U.S., also Chief Engineer of Provincial Works in the island.
 52. Quesada, Appendix.
 53. For example, two of many others throughout LASCs and PASCs, Dr. Andrade spoke of potential oil regions in Ecuador, and Minister F. A. Pezet lectures on Peru's mineral resources. *Daily Bulletin/Boletin Diario*, Dec31, 1915, 4.
 54. Curiously, he used "lantern slides". *Daily Bulletin/Boletin Diario*, Dec31, 1915, 1.
 55. "2PASC," *Bulletin of the Pan American Union*, 774-775; *Daily Bulletin/Boletin Diario*, Dec 28,1915, 4.
 56. *Daily Bulletin, Boletin Diario*, Jan 4, 1915; "2PASC" in *Bulletin of the Pan American Union*, passim; World Peace Foundation, "2PASC," in *The New Pan Americanism; Pamphlet Series*, 6, 2 (April 1916), passim;
 57. *Daily Bulletin/Boletin Diario*, Jan. 5, 1916, 1; *New Pan Americanism*, 108. It was a highly pervasive theme.
 58. *New Pan Americanism*, 105.
 59. Op. Cit (18-22).
 60. Teodosio Gonzalez, *Una gira por el Pacifico; La hospitalidad Chilena, El Congreso Cientifico de Santiago; Impresion de un Delegado Paraguayo*

- (Asuncion: Talleres Graficos La Union, 1909), passim; *Daily Bulletin/Boletin Diario*, Ja 4,1916, 1. 4; Gutierrez, passim.
61. 2LASC, *Organizacion y resultados*, 55-70; 3LASC, *Relatorio Geral*, 151-157; *Daily Bulletin/Boletin Diario*, Jan. 4,1916.
 62. Paul S. Reinsch, *Public International Unions: Their Work and Organization; A Study in International Administrative Law* (Boston: Ginn & Co., 1911), 35-49. There were a number of meetings pertaining to time standardization in LASCs. The first of these was the conflict between 'Federico' Ristenpart and 'Carlos' Hesse. Hesse suggested a change of calendar division into 13 months, of 28 days each. Ristenpart objected because 12 was divisible by 2,3,4 while 13 not-thus making calculations much more difficult if changed. However, Ristenpart acknowledged that some reform of the Georgian Calendar was needed, and that a special session should be consequently formed. That the issue was even debated perhaps points to the flexibility and fluidity of themes that existed at the time. The second issue was the creation of common time, using Greenwich as base point. Since there was no universal frame of reference, and each region in Latin America had own time. It was commented as to how easy it would be that, when traveling to Chile, members would only have to adjust their watch by an hour—a structure we moderns take for granted! *Chile ante el Congreso*, 28-30. Issues also discussed by Francisco Porro de Somenzi's report; Somezi seems to have actually opposed such reform! Felix F. Outes, ed., *La Universdiad Nacional de la Plata en el IVo Congreso Cientifico, 1o PanAmericano* (Buenos Aires: Impt. Edt. Casa Hermanos: 1909), 37-41.
 63. "The Second Pan American Scientific Congress," *BPAU*, 796
 64. M. P. Crosland, "Aspects of International Scientific Collaboration and Organization before 1900," in *Human Implications of Scientific Advance*. ed. E. G. Forbes (Edinburgh: University Press, 1977), 119-122, 115-117; Maurice Crosland, "The Congress of Definitive Metric Standards, 1798-199, The First International Scientific Conference?" *ISIS* 60, 202 (Summer 1969): 226-271. According to Robertson, however, international scientific cooperation did not really emerge until after the W.W.I period. It seems that there were two different kinds of congresses—the pre 1900 mainly dealt with 'applied sciences,' while the consequent ones produced new scientific ideas. Peter Robertson, "Niels Bohr and international cooperation in science," *Impact of Science on Society*, 137 (1988), 15-21.

65. Döll pointed out in 1920 that had Massachusetts instituted a uniform cartographic system, it would have saved itself something like \$80M. Correlating the different systems was also something of a headache; ironically, it was necessary work which invisibly underlay many other projects but which consequently was not appreciated by the public. Carlos Malsch, "Conveniencia de adoptar metodos de ensaye y análisis uniformes en los casos litigiosos o de controversia: Creacion de un Comité Pan-Americano permanente, para el establecimiento oficial de estos metodos," in *Ciencia Químicas*, ed. Belisario Diaz Ossa, vol. 4, *Trabajos del cuarto Congreso Científico (1.º Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910), 161-166; Francisco Porro di Sumenzi, "Sobre medicion de un gran arco meridiano sud-americano" in *Matemáticas Puras y Aplicadas*, Ricardo Poenish, ed., vol. 6, *Trabajos del cuarto Congreso Científico (1.º Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910), 132-137; Don Enrique Döll, "Discurso de incorporacion a la Facultad de Ciencias Físicas i Matemáticas de la Universidad de Chile" *Anales de la Unviersidad* 146, 78 (jan-feb 1920), 8.
66. 2lasc, *Organizacion y resultados*, 88, 95; Poirier, *Resena General*, 179-207; Alberto Gutierrez, *Informe presentado al Ministerio de Relaciones Exteriores de Bolivia* (La Paz: Imprenta Velarde, 1916).
67. After the opening day of 3LASC, there was a reception at the Presidential Palace, hosted by Dr. Francisco de Paula Rodriguez Aviles—not an insignificant event. 3LASC, *Relatorio Geral*, 151-157. A nation's president would also take time to meet with scientific representatives, as when Teodosio Gonzalez of Paraguay met Juan L Cuestas, president of Uruguay. Samuel Aguinaga, ed., *El Parguay en el Exterior: Congreso Científico de Montevideo* (Montevideo: Imprenta. de El Siglo, 1901), 36.
68. "1PASC" *Bulletin of the International Bureau*, 596; Aguinaga, *passim*; Daily Bulletin/Boletin Diario, *passim*.
69. Elihu Root, "The Pan-American Spirit," in *The Outlook* (Oct 20, 1906), 411.
70. Dr. Manoel Avalro de Souza Sá Vianna, *Arbitragem Internacional, 2o Congresso Científico Latino Americano* (Rio de Janeiro: typ. Aldina, 1901), 21-22, 55-56. Note that since volume dealt mainly with law, this was one of

main issues addressed. Samuel Guy Inman, *Inter-American Conferences 1826-1954: History and Problems* (Washington DC: University Press, 1965), passim.

71. 3LASC, *Relatorio Geral*, 171-176. The issue was also a part of the proceedings. Because of its scientific nature, it will be more fully discussed later.
72. Other officers included, two vice presidents, Carlos R Tobar (Ecuador) and Luis Demicheri (Uruguay); and two secretary generals: Dr. Gregorio Araoz Affaro (Argentina), and Dr. Alfredo Navarro (Uruguay). During 2LASC, Jose Arechavaleta, President of Organizing Executive Committee, passed the presidency to Dr. Robert Wernicke, of Argentina; as Letelier later did in 1PASC. Reinsch, who observed the applause, commented that, "a representative Chilean audience had the opportunity to show its desire to bury old hatreds." The examples are endless. Valetin Letelier, President of Chilean organizing committee, had expressed the pan-American ideal to Rowe in his letter of invitation, "resultados que de el se esperan, [ie] respecto a la atinada diuclidacion de importantes problemas cientificos, cuyo estudio interesa a estos pueblos, y a la creacion enter ellos de poderosos lazos de amistad...." Similar comments were made by all invitees. 1PASC, *Segundo Boletin*, 9, 66; 2LASC, *Organizacion y Resultados*, 55-70. Reinsch, *International Unions* 57; Inman, *Inter-American Conferences*, passim.; Gutierrez, 12-13; 1LASC, *Anales*, 1898, 255; Dr. Conio, "1LASC".
73. At 2LASC, Teodosio Gonzales felt that "la delgacion paraguaya fue la nina amada del pueblo, prensa y gobierno Oriental..." All of Paraguayan delegates gave very favorable reports about their reception in Uruguay. Reinch, *Indepedent*, 373; Aguinaga, 34.
74. Mr. Calvalho said, "Mas o sentimento individual, colectivo ou social que desperta e o de admiracão, o de entusiasmo pelo homem, por seu genio, por seu esorço, pelos resultados obtidos." 3LASC, *Relatorio Geral*, 158, 164; 2lasc, *Organizacion y resultados*, 4, 58;
75. 3LASC, *1o Boletim*, passim.
76. An example would be the observatory at San Lucia founded after visit by Gillis for observations of Venus in 1849. *Chile ante el Congreso*, 28; 31

77. Yet instead of calling for an educational reform in which science is laid greater stress, states that education should be in conformity to actual state and 'needs', thus proposing the strengthening patriotic sentiment, inspiring national soul, aiding the ends of state, and so on. Ironically, while recognizing science's importance, Alvarez's suggestions did nothing whatsoever to actually stimulate it. *Ibid.*, 54-5.
78. Dr. Pereira, 61-3.
79. 3LASC, *Relatorio Geral*, 163.
80. William Shepherd, "The Scientific Congress at Santiago," *Columbia University Quarterly* (June 1909), 332-337 332-333.
81. Poirier, *Resena General*, 275-285; 2LASC, *Organizacion y Resultados*, 196. The first PAC was held at Panama in 1826. Inman, *Inter-Amer Conf*, 1-20.
82. "The Second Pan American Scientific Congress," *Bulletin of the Pan American Union*, 41, 6 (December 1915), 756.
83. Poirier, *Resena General*, 1 PASC, 140-1; Alan Sokal and Jean Brickmont, *Fashionable Nonsense: Postmodern Intellectual's Abuse of Science* (New York: Picador Press, 1998), chpt 12. Chomsky, for example, writes, "Remarkably, their left counterparts today often seek to deprive working people of these tools of emancipation...that we must abandon the illusions of science and rationality—a message that will gladden the hearts of the powerful, delighted to monopolize these instruments for their own use." *Ibid.*, 204.
84. Samuel Guy Inmnan, *Problems in Pan Americanism* (New York: George H. Doran Co., 1925); Joseph Byrne Lockey, *Essays in Pan-Americanism* (Port Washington, New York: Kennikat Press, 1939); William Spence Robertson *Hispanic-American Relations with the United States* (New York: Oxford U Press, 1923, reprint 1960). Note that Lockey's piece is an edited compilation of his earlier work. More modern works would include: Whitney T. Perkins, *Denial of Empire: the United States and Its Dependencies* (Leyden: A. W. Sythoff, 1962); Julius W. Pratt, *America's Colonial Experiment: How the United States Gained, Governed, and In Part Gave Away a Colonial Empire* (New York: Prentice Hall, 1951); Robert Beisner. *Twelve Against Empire: The Anti-Imperialists, 1898-1900* (Chicago: University of Chicago Press, 1968, 1985); David Healy, U.S.

Expansionism: The Imperialist Urge in the 1890's (Madison: University of Wisconsin Press, 1970); Howard K Beale, *Theodore Roosevelt and the Rise of America to World Power* (New York: Collier Books, 1956); Julius W. Pratt, *The Expansionists of 1898: The Acquisition of Hawaii and the Spanish Islands* (Chicago: Quadrangle Books, 1936, reprint 1964).

85. *Daily Bulletin*, December 29, 1915
86. Harrison points out that U.S. investment in Latin America, at least in the post W.W.II period has sharply declined; most of U.S. funds actually rest in the more developed regions of the world: Japan, Europe, and Brazil, one of the first countries to have industrialized in Latin America. Investment overseas makes up 5% of total U.S. investment; 70% of which goes to developed countries; Latin America receives only 20%—which amounts to about 1-2% of total U.S. investment. Even then, investment in Latin America had been declining since W.W.II—50% of world trade in 1950, 32% in 1980. In contrast to dependency theorist claims, most of U.S. economic growth has been internal to the nation, rather than by the transfer of wealth from other regions of the world which it had commercial relations with. Pike also points out that U.S. economic growth preceded its ties to Latin America. During the nineteenth century, U.S. economic growth significantly outpaced Latin Americas. For example, between 1800 and 1845, Mexico's income fell to 56 pesos from 166, while U.S. doubled; while Mexico's output equaled 51% of U.S. GNP, it had declined to 8% by 1845. Lawrence Harrison, *Underdevelopment is a State of Mind: The Latin American Case* (Lanham, MD: Center for International Affairs, Harvard University, 1985); Frederick B. Pike, *The United States and Latin America: Myths and Stereotypes of Civilization and Nature* (Austin: University of Texas Press, 1992), 74.
87. Inman, *Problems with Pan Americanism*, passim; Philip C. Jessup, *Elihu Root*, 2 vols. (New York: Dodd, Mead and Co., 1938), 1, 314.
88. Andrew Carnegie also donated money to build the Pan American Union building.
89. "2PASC", *Bulletin of the Pan American Union*, 778-796; James Brown Scott, ed., *The Final Act and Interpretative Commentary Thereon, Second Pan American Congress* (Washington DC: U.S. GPO, 1916), appendix # 7.

90. Richard Shryock, "American Indifference to Basic Science during the Nineteenth Century," *Archives Internationales d'Histoire des Sciences* 28 (1948-9), 3-18; Nathan Reingold, "American Indifference to Basic Research: A Reappraisal" in George H. Daniels, ed. *Nineteenth-Century American Science: A Reappraisal* (Evanston: Northwestern University Press, 1972), 38-61; Judy Crichton, *America 1900: The Turning Point* (New York: Henry Holt & Co, 1998); Richard Hofstadter, *Anti-Intellectualism in American Life* (New York: Vintage Books, 1963); Max Learner, *America as a Civilization: Life and Thought in the United States Today* 13th ed (New York: Henry Holt & Co, 1987), 216-226; Edwin Layton, "Mirror-image twins: the communities of science and technology in 19th-century America," *Technology and Culture* 12 (1971), 562-80. The demands and values of a business culture undermine activities that do not seem to have immediate profit, applicability or gain, and thus create a social atmosphere inhibitory of the free-flow of ideas or appreciative of such speculation. Yet fundamental science cannot progress when it knows where it is headed. Ironically, as John Stuart Mill, pointed out in his critique of Comte's utopia, these initial discoveries provide the later bases of economically remunerative activities—a model which was the basis of U.S. science policy in the post W.W.II period. John Stuart Mill, *Auguste Comte and Positivism*. reprint, (Ann Arbor: University of Michigan Press, 1961); Bruce L. R. Smith, *American Science Policy Since World War II* (Washington D.C.: The Brookings Institution, 1990).
91. Seymour Martin Lipset, *The First New Nation: The United States in Historical and Comparative Perspective* (New York: W.W. Norton, 1979). The relative ease of social mobility in the US, in contrast to the more rigid and hierarchical European society, has had a tremendous impact on interpersonal relations. See Dana Munro, *Intervention and Dollar Diplomacy in the Caribbean, 1900-1921*. (Princeton: Princeton University Press, 1964), chpt. 4. for a description of Root's efforts.
92. Sylvester Baxter, "The Western World in Conference: Rio de Janeiro and the Conference at the Palace Monroe," *The Outlook* (Oct. 20, 1906), 172; Eduardo Poirier, ed. *Chile en 1908: Obra dedicada a los senores delegados y adherentes al IV Congreso* (Santiago de Chile: Impt. Lit. y Encu. Barcelona, 1909), 242.
93. Valentin Letelier, *Memorias Universitarias* (Santiago de Chile: Imprenta Cervantes, 1908), 169; Luis Galdames, *Valentin Letelier y Su Obra, 1852-*

- 1919 (Santiago de Chile: Imprenta Universitaria, 1937), 534-558; Lipp, Simon. *Three Chilean Thinkers: Francisco Bilbao, Valentin Letelier, and Enrique Molina* (Waterloo, Canada: McGill University, 1975.); Sehlinger, Peter J. "Valentin Letelier y la historiografía positiva en Chile durante el siglo XIX." *Revista Chilena de Historia y Geografía*. 145 (1977): 113-124; Allen Woll, *A Functional Past: The Uses of History in Nineteenth Century Chile* (Baton Rouge: Louisiana State University Press, 1982)
94. 4o Congreso Científico, 1ro Pan Americano, *2do Boletín: Trabajos Preparatorios Hata el 30 de Junio de 1908* (Santiago de Chile: Imp. Litog. Encd. "La Ilustración", 1908), passim; Eduardo Poirier, ed. *Chile en 1908: Obra dedicada a los señores delegados y adherentes al IV Congreso* (Santiago de Chile: Impt. Lit. y Encu. Barcelona, 1909); Eduardo Poirier, *Resena General del 4.º Congreso Científico, 1.º Pan-Americano* (Santiago de Chile: Imp. Lit. y Enc. Barcelona, 1915), 4, 5, passim.
 95. Poirier, *Resena*, 49, 68.
 96. Official Delegates included: Dr. Hiram Bingham, Yale; Dr. Arhcibald Cary Coolidge, Harvard; Col. William C Gorgas, US Army; Dr. W. H. Holmes, Smithsonian Institution; Dr. Bernard Moses, University of California; Dr. Paul S. Reinsch, University of Wisconsin; Dr. George H. Rommel, Dept. of Agriculture; Dr. L. S. Lowe, University of Pennsylvania; Dr. W. R. Shepherd, Columbia University; Dr. W. B. Smith, Tulane University. Non-official delegates included: Dr. Albert A. Michelson, University of Chicago; Dr. J. L. Laughlin, University of Chicago; Mr. Orville A. Derby, Cornell University; Dr. Thomas Barbour, Harvard University; Dr. J. B. Woodworth, Harvard University; Dr. A. Hempel, University of Illinois; Dr. H. D. Curtis, University of Michigan; Dr. C. W. Hall, University of Minnesota; Dr. W. F. Rice, Northwestern University; Dr. W. E. Browning, Princeton University; Dr. D. E. Salas, National Education Association.
 97. This probably is the reason why Latin American scholars have not covered the subject. The other U.S. candidates are not discussed because they are either outside 'natural philosophy' or were not as scientifically important.
 98. Although in other occasions Einstein would claim that the two were entirely separate. His influence has been subject of a great deal of historical debate. Banesh Hoffmann, *Albert Einstein: Creator and Rebel* (New York: Penguin Books, 1972), 69-72; Gerald Horton, "Einstein, Michel-

- son, and the 'Crucial' Experiment,' *ISIS* 60, 292 (Summer 1969), 133-198.
99. Stanley Goldberg, and Roger H. Stuewer, eds., *The Michelsonian Era in American Science, 1870-1930* (New York: American Institute of Physics, 1988); Bernard Jaffe, *Michelson and the Speed of Light* (Westport, Connecticut: Greenwood Press, 1960); E. Whitakker, *A History of the Theories of Aether and Electricity*, vol. 1 (London: Thomas Nelson, 1951); Russell McCormach, "H. A. Lorentz and the Electromagnetic View of Nature," *ISIS* 61, 4 (Winter 1970), 459-498; Bruce J Hunt, "The Origins of the Fitzgerald Contraction" *BJHS* 21 (1988), 67-76; Thomas Parke Hughes, *Science and the Instrument-maker: Michelson, Sperry, and the Speed of light* (Washington DC: Smithsonian Institution Press, 1976).
 100. A Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities* (Baltimore: Johns Hopkins University Press, 1986), passim; Daniel Lee Kleinman, *Politics on the Endless Frontier: Postwar Research Policy in the United States* (Durham, NC: Duke University Press, 1995), passim.
 101. Katherine Russell Sopka, *Quantum Physics in America, 1920-1935* (N.Y.: Arno Press, 1980), part 1
 102. Paul Forman, John Heilbron, and Spencer Weart, *Physics ca 1900. Personnel, Funding, and Productivity of the Academic Establishments*. vol. 5. *Historical Studies in the Physical Sciences*. 1975 ed Russell McCormach (Princeton: Princeton University Press, 1975), chpt. 1; Derek de Solla Price, *Little Science, Big Science* (New York: Columbia University Press, 1963), passim.
 103. Lawrence Badash, "The Completeness of Nineteenth Century Science," *ISIS* 63 (1972), 48-58. He held these views as late as 1899, but it is known that Robert Millikan said that Michelson eventually recanted. Exactly how far they persisted is of some significance. Had these views been persistent by 1908, they would have also significantly influenced the emerging physics community in Chile. The author has been unable find an answer.
 104. Albert E. Moyer, *American Physics in Transition: A History of Conceptual Change in the Late Nineteenth Century* (Los Angeles: Tomash Publishers, 1983), chpts. 14, 15; Katherine R Sopka, ed. *Physics for a new century: papers presented at the 1904 St Louis Congress* (New York: American Insti-

tute of Physics, 1986); quote in Daniel Kevles, "The Physics, Mathematics, and Chemistry Communities: A Comparative Analysis" in Alexandra Oleson and John Voss, eds., *The Organization of knowledge in Modern America, 1890-1920* (Baltimore: Johns Hopkins University Press, 1979), 152; Abraham Pais, *Inward Bound: Of Matter and Forces in the Physical World* (New York: Oxford University Press, 1986), 38, chpt. 3. The history of scientific journalism is not too well developed. See Dorothy Nelkin, *Selling Science: How the Press Covers Science and Technology* (New York: W. H. Freeman & Co., 1987).

105. Warren Browne, *Titan vs Taboo: The Life of William Benjamin Smith* (Tucson, Arizona: The Diogenes Press, 1961).
106. Very much like Oppenheimer, when Smith got tired of physics, he studied Sanskrit and Indian religion.
107. Lewis Pyenson, "Einstein's Early Scientific Collaboration," *Historical Studies in the Physical Sciences*, 7 (1982), 284-92; Lewis Pyenson, "Mathematics, education, and the Gottingen approach to physical reality, 1890-1914," *Europa* 2, 2 (1979), 91-127; Christa Jungnickel and Russell McCormach, *Intellectual Mastery of Nature: Theoretical Physics from Ohm to Einstein*, 2 vols., Chicago: University of Chicago Press, 1986), passim.
108. John Higham, "The Matrix of Specialization," in Alexandra Oleson and John Voss, eds., *The Organization of knowledge in Modern America, 1890-1920* (Baltimore: Johns Hopkins University Press, 1979), 3-18.
109. This might have been due to the poor quality of theoretical and mathematical work in America at this time. Perhaps finding little stimulus, he shifted to a field with plenty of participants.
110. David Bohm, who was forced to live in Brazil, was negatively affected by it. Even his consequent move to Israel did not remedy the situation. Einstein quoted in Russell Olwell, "Physical Isolation and Marginalization in Physics: David Bohm's Cold War Exile," *Isis* 90, 4 (1999), 751.
111. Many other delegates, Gorgas, Michelson, and Curtis included, obviously delivered English lectures, onto which were appended Spanish translations. Smith's is one of the few who did not have an English manuscript in the congress's transcripts, suggesting that the original presentation had been in Spanish. Given his academic background in Romance languages, this is not unlikely.

112. John M. Gibson, *Physician to the World: The Life of General William C. Gorgas* (Durham, NC: Duke University Press, 1950), 65; David McCullough, *The Path Between the Seas: The Creation of the Panama Canal, 1870-1914* (New York: Simon & Schuster, 1977), chpts. 15-17; Nancy Stepan, "The interplay of socio-economic factors and medical science: Yellow Fever research, Cuba, and the United States," *Social Studies of Science* 8 (1978), 397-423; Howard A. Kelly, *Walter Reed and Yellow Fever* (Baltimore: Norman, Remington Co, 1923).
113. William Crawford Gorgas, *Sanitation in Panama* (New York: D. Appleton & Co, 1915); Jerome R. Ravetz, *Scientific Knowledge and Its Social Problems* (New York: Oxford University Press, 1971), chpt. 9; John Ettling, *The Germ of Laziness: Rockefeller Philanthropy and Public Health in the New South* (Cambridge: Harvard University Press, 1981).
114. Although the Cuban physician Carlos Finlay had certainly postulated that mosquitoes were disease vectors in the tropical world, he is not given credit as its founder because he had not shown the exact mechanisms and dynamics of its transmission. Finlay did not understand that the insect was not only an agent, but was also a host of the disease—a factor inhibiting any positive replication of his experiments. Mason first realized the connection while working in China during the 1870's and 1880's. He had noticed a correlation between the periodicity of filarial eggs in the bloodstream and the spread of the disease, in this case elephantiasis. During waking hours no eggs could be observed, but during sleep the numbers skyrocketed into the millions, thereby allowing mosquitoes nesting in the walls of the thatched huts to intake these in their own internal systems after feeding. Mason, however, had not fully understood the cycle in China—something which his student Ronald Ross would in 1897. It was not, as Mason believed, that the eggs were deposited by the mosquitoes in water and through this medium entered the human bloodstream. Instead, Ross found that the eggs developed into larvae within the mosquito and, by the same means which they had received it (i.e. biting), the mosquitoes deposited the larvae into the human system. Following Ross's discovery, institutes of tropical medicine spread rather rapidly throughout the turn of the century. Tropical medicine did not have one founder but rather many founders. Philip Manson-Bahr, *Patrick Manson: the Father of Tropical Medicine* (London: Thomas Nelson and Sons Ltd, 1962); Francois Delaporte, *The History of Yellow Fever An Essay on the Birth of Tropical*

- Medicine*, transl. Arthur Goldhammer, (Cambridge, MA: MIT Press, 1991), David Arnold, ed., *Warm Climates and Western Medicine: The Emergence of Tropical Medicine, 1500-1900* (Amsterdam: Rodopi, 1996); Michael Worboys, "Tropical Medicine" in R. C. Olby, G N Cantor, et all., *Companion to the History of Modern Science* (London: Routledge, 1990), chpt. 24.
115. Paul Starr, *The Social Transformation of American Medicine* (New York: Basic Books, Inc., 1982), chpt. 3; Daniel Kevles, "The Physics, Mathematics, and Chemistry Communities: A Comparative Analysis" in Alexandra Oleson and John Voss, eds., *The Organization of knowledge in Modern America, 1890-1920* (Baltimore: Johns Hopkins University Press, 1979), 139-172.
 116. Heber D. Curtis, "Velocidades radiales de estrellas australes con grandes movimientos propios" in *Matemáticas Puras y Aplicadas*, ed. Ricardo Poenish, vol. 6, *Trabajos del cuarto Congreso Científico (1.º Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910), 184-187; Heber D. Curtis, "Estrellas dobles australes descubiertas en el espectroscopio por el Observatorio de la D. O. Mills Expedicion," in *Matemáticas Puras y Aplicadas*, ed. Ricardo Poenish, 179-181.
 117. Robert G. Atiken, "Biographical Memoir of Heber Doust Curtis, 1872-1942" *Biographical Memoirs*, 23. National Academy of Sciences, 274-294; Michael A Hoskin, "Curtis, Heber Doust," *Dictionary of Scientific Biography*, 508-9; Heber D. Curtis, "Spectrographic and Photographic Observations of Comet c 1908 (Morehouse)," *Lick Observatory Bulletin* 163 (1911), 135-138; Heber D Curtis, "Five Stars having Variable Radial Velocities," *Lick Observatory Bulletin* 146 (1909), 60-1; Heber D. Curtis, "The Distance of the Stars," *Publications of the Astronomical Society of the Pacific* 23, 137 (June-Aug. 1911), 143-163; Heber D. Curtis, "Thirteen Stars having Variable Radial Velocities," *Lick observatory Bulletin* 164 (1912), 139-140; Heber D. Curtis, "Methods of Determining the Orbits of Spectroscopic Binaries," *Publications of the Astronomical Society of the Pacific* 20, 120 (June 1908), 133-155; William McGucken, *Nineteenth Century Spectroscopy: Development of the Understanding of the Spectra, 1802-1897* (Baltimore: Johns Hopkins University Press, 1969); Owen Gingerich, ed., *Astrophysics and twentieth-century astronomy to 1950:*

- part A., Michael Hoskin, ed., *The General History of Astronomy*, vol. 4 (Cambridge: Cambridge university Press, 1984).
118. Oddly, most astronomers gravely opposed the methods of astrophysics, because of their initial lack of rigor and ‘mental discipline’ required for the new astrophysics—most astrophysicists did not have advanced mathematical training but instead had rather been self-taught as Curtis.
 119. M. A. Hoskin, “‘The Great Debate’: What Really Happened,” *Journal for the history of Astronomy* 7 (1976), 169-182; M. A. Hoskin, “Ritchey, Curtis and the Discovery of Novae in Spiral Nebulae,” *Journal for the History of Astronomy* 7 (1976), 47-53; Robert W. Smith, *The Expanding Universe: Astronomy’s ‘Great Debate’, 1900-1931* (Cambridge: Cambridge University Press, 1982); Charles A. Whitney, *The Discovery of Our Galaxy* (New York: Alfred A. Knopf, 1971).
 120. Heber D. Curtis, “The Distance of the Stars,” *Publications of the Astronomical Society of the Pacific* 23, 137 (June-Aug 1911), 155.
in Curtis, “The Distance of the Stars”, 161.
 121. H. W. Duerbeck, D. E. Osterbrock, L. H. Barrera S., R. Leiva, “Halfway from La Silla to Paranal—in 1909” *The Messenger*, 95 (March 1999), 34-37.
 122. A second car was purchased in 1915.
 123. John Lankford, *American Astronomy, Community, Careers, and power, 1859-1940* (Chicago: University of Chicago Press, 1997); J. B. Hershaw, *The Analysis of Starlight: One Hundred and Fifty Years of Astronomical Spectroscopy* (Cambridge: Cambridge U. Press, 1986), chpt. 6; Donald E. Osterbrock, John R. Guftafson, and W. J. Shiloh Unruh, *Eye on the Sky: Lick Observatory’s First Century* (Berkeley: University of California Press, 1988), chpt. 8.
 124. Hale had organized the Congress on Astronomy as part of Congress of Arts and Sciences of St. Louis World’s Fair in 1904, and had been the founder of astrophysics’ leading journal and organization.
 125. Deborah Hitzeroth, *Telescopes: Searching the Heavens* (San Diego: Lucent Books, 1991); Isaac Asimov, *Historia del Telescopio* (Madrid: Alianza Editorial, 1986); Daniel Malacara and Juan Manuel Malacara, *Telescopio y Estrellas* (Medico D.F.: Fondo de Cultura Economica, 1988); Donald E. Osterbrock, *Pauper and Prince: Ritchey, Hale, and Big American Telescopes*

- (Tucson: University of Arizona Press, 1993), 25, 66; Albert Van Helden, "Telescope building, 1850-1900" in Owen Gingerich, ed., *Astrophysics and twentieth-century astronomy to 1950: part A*, 40-59.
126. Henry B. Bigelow, "Thomas Barbour, 1884-1946," *Biographical Memoirs*, National Academy of Science 27 (1952), 13-27; "Dr. Thomas Barbour," *Nature* 157 (Feb 23, 1946), 220.
 127. Barbour gave a talk on "Recent studies in experimental evolution," mentioned in *Report of the Delegates of the United States to the Pan American Scientific Congress, held at Santiago, Chile December 25, 1908 to January 5, 1909*. (Washington DC: US GPO, 1909), Appendix B. The paper appears nowhere in the Congress's twenty-volume compilation. Primer Congreso Científico Pan-Americano, *Trabajos del cuarto Congreso Científico (1.º Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)*. (Santiago de Chile: Imp. Enc. y Lit.Barcelona, 1910). The author has been unable to locate a copy of Barbour's paper. Was Barbour a bridge between the two diverging approaches in American biology? Was the suppression of Barbour's presentation mainly due to an 'incommensurability' between the two cultures; with differing intellectual traditions, they simply could not identify its importance? Another problem might rest in the fact that Latin Americans generally defined 'science' differently from North Americans—despite the similarities in their emphasis on the 'practical'. Note that Barbour's presentation was purely scientific and had no immediate applications.
 128. Yet how well Latin American editors could have assessed Barbour's merit is hard to tell. It is likely that they judged by formal professional credentials as opposed to the internal content of his presentation. Bingham, who was also a young scholar, had been given more recognition. In contrast to Barbour, Bingham already had a long list of distinguished 'positions' at leading U.S. universities, however vacuous they might have been. Barbour's research up to date was, however, was much more thorough and voluminous than Bingham's.
 129. One should note that Darwin's own views about natural selection were a bit more open ended than that of turn of the century Darwinists as August Wiesman's.
 130. Garland E. Allen, *Life Sciences in the Twentieth Century* (New York: John Wiley & Sons, Inc., 1975); Ronald Rainger, Keith Benson, Jane Maien-

- schein eds., *The American Development of Biology* (New Brunswick: Rutgers University Press, 1988); Peter J. Bowler, *Evolution: The History of an Idea* (Berkeley: University of California Press, 1989); Edward J. Pfeifer, "United States," in Thomas F. Glick, *The Comparative Reception of Darwinism* (Austin, University of Texas Press, 1972), 168-206; Jane Maienschein, *Transforming Traditions in American Biology, 1880-1915* (Baltimore: Johns Hopkins University Press, 1991); Margaret W. Rossiter, "The Organization of the Agricultural Sciences" in Alexandra Oleson and John Voss, eds., *The Organization of knowledge in Modern America, 1890-1920* (Baltimore: Johns Hopkins University Press, 1979); Garland Allen, "The Transformation of a Science: T. H. Morgan and the Emergence of a New American Biology," in *Ibid*, 206; Cynthia Eagle Russett, *Darwin in America: The Intellectual Response, 1865-1912* (San Francisco: W. H. Freeman & Co, 1976).
131. Despite these general traits, Barbour however did show a great deal of awareness to the new research paradigms, and to this extent served as a bridge between the older and newer schools of American biology. Like many of his experimentalist colleagues, Barbour attacked the process of mimicry and coloration, which had in the 1880's been used as proof for the Darwinian scheme. Sharon Kingland, "Abbott Thayer and the Protective Coloration Debate," *Journal of the History of Biology* 11, 2 (Fall 1978), 223-244; Peter J. Bowler, *The Eclipse of Darwinism: Anti-Darwinian Evolution Theories in the Decades around 1900* (Baltimore: Johns Hopkins University Press, 1983), 29-30.
 132. Curiously, E.O. Wilson almost a century later would have to defend his profession as a naturalist against the incursions of molecular biologists. E. O. Wilson, *Naturalist* (Washington D.C.: Island Press, 1994).
 133. James A Secord, "The discovery of a vocation: Darwin's early geology," *British Journal for the History of Science* 24 (1991), 133-57; Thomas Barbour, *A Naturalist at Large* (Boston: Little, Brown and Company, 1943).
 134. Barbour did not use, nor could have used, the term.
 135. Mary P. Winsor, *Reading the Shape of Nature: Comparative Zoology at the Agassiz Museum* (Chicago: University of Chicago Press, 1991), 245-266; Barbour, 1945, passim, 236-8.
 136. Similarly the long list of credentials that had appeared in the PASC's short biography of Bingham were rather deceptive; an academician he was not.

This perhaps explains his general cool reception by Yale's history department.

137. Alfred M. Bingham, *Portrait of an Explorer: Hiram Bingham, Discoverer of Machu Picchu* (Aimes: Iowa State University Press, 1989); Hiram Bingham, *Across South America: An Account of a Journey From Buenos Aires to Lima by way of Potosi, with note on Brazil, Argentina, Bolivia, Chile, and Peru* (Boston: Houghton Mifflin Co, 1912), chpts. 14, 27.
138. Pan American Medical Congress, *Transactions of the First Pan-American Medical Congress, held in Washington D.C., September 5-8, 1893* (Washington: U.S. GPO.,?); Segundo Congreso Medico Pan-Americano, *Memorias del Segundo Congreso Medico Pan-Americano verificado en la ciudad de Mexico D.F., Noviembre 16-19 de 1896* (San Francisco: Hoeck y Compania Impresores y Editores, 1898); Tercer Congreso Medico Pan-Americano, *Actas de las sesiones y memorias presentadas al Tercer Congreso Medico Pan-Americano, Habana (Cuba) 4-7 de febrero de 1901* (Habana: La Moderna Poesia, 1902). There were two others, 1906 and August 1908, but information hadn't probably diffused enough, otherwise Gorgas would not be repeating it. Cuarto Congreso Medico Pan-Americano, *Anales del Cuarto Congreso Medico Pan-Americano* (Panama: Chevalier, Andere & Co, 1906). Quinto Congreso Medico Pan-Americano, *Boletín oficial del Quinto Congreso Medico Pan-Americano, Guatemala, 6-10 de agosto de 1908* (Guatemala: Imprenta Nacional, 1908).
139. Dr. M. J. Rosenau, "Ultimos adelantos en el estudio de la fiebre tifoidea," in *Ciencias Medicas E Higiene*, ed. German Greve, vol. 1, *Trabajos del cuarto Congreso Científico (1.º Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910), 221-229; Simon Flexner and James W. Jobling, "Análisis de cuatrocientos Casos de Meningitis Epidemica tratados con el Suero Anti-meningítico," in *Ciencias Medicas E Higiene*, ed. Greve, 153-157.
140. Marcos Cueto, ed., *Missionaries of Science: The Rockefeller Foundation and Latin America*. (Bloomington: Indiana University Press, 1994), passim.
141. There were a few exceptions, as Dr. Ashford who became a hero in Puerto Rico for eliminating the prevalent hookworm. For centuries, the Spanish had believed it to be anemia. Bailey K. Ashford, *A Soldier in Science: The Autobiography of Bailey K Ashford* (New York: William Morrow and Co., 1934).

142. Col. W. C. Gorgas, "Saneamiento de los Tropicos en lo que se refiere especialmente a la malaria o a la fiebre amarilla," in *Ciencias Medicas E Higiene*, ed. Greve, 118-123; Dr. H. R. Carter, "Apuntes sobre los metodos de nanidad en al fiebre amarilla y la malaria resultado de experiencias practicadas en el Itsmo" in *Ciencias Medicas E Higiene*, ed. Greve, 131-138
143. Tomás A. Ramirez, *Ciencias Juridicas*, vol. 7, *Trabajos del cuarto Congreso Cientifico (1.O Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910).
144. A. A. Michelson, "Recientes progresos en la Espectroscopia" in *Ciencias Fisicas*, Jose Ducci, ed., vol. 5, *Trabajos del cuarto Congreso Cientifico (1.O Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910), 25-30.
1PASC, 25-29
145. Michelson also went into some detail describing the history and improvements of his interferometer. Initially formulated by Newton, Michelson had been able to obtain very high levels of precision by using the red light emitted by a 'vapor de cadmio', which produced the most stable light source. Consecutive readings had led to differences no greater than a millionth part.
146. William Benjamin Smith, "Nuevas teorias de los fenomenos fiscicos," in *Ciencias Fisicas*, 2-23.
147. Smith., 2.
148. This is not meant to underestimate the difficulty of physics in its pre-quantum mechanics phase. As is now well known, Irving Langmuir, who would later get a Nobel Prize, was unable to learn this physics in 1903 when he went to Gottingen. The experience was not uncommon to many North American students in Germany. However, judgment is always relative to something else, and not intrinsic to its properties. Although certainly complicated, the field did not have the mathematical sophistication that would characterize it during the emergence of Werner Heisenberg, Max Born, and Wolfgang Pauli's matrix (quantum) mechanics of the 1920's. John W. Servos, "Mathematics and the Physical Sciences in America, 1880-1930," *Isis* 77 (1986), 611-629; Jed Z. Buchwald, *From Maxwell to Microphysics: Aspects of Electromagnetic Theory in the Last Quar-*

ter of the Nineteenth Century (Chicago: University of Chicago Press, 1985); Bruce J. Hunt, *The Maxwellians* (Ithaca: Cornell University Press, 1991).

149. Abraham Pais, *Inward Bound: Of Matter and Forces in the Physical World* (New York: Oxford University Press, 1986), chpt. 4, 103-4, 180-1; Steven Weinberg, *Dreams of a Final Theory* (New York: Pantheon Books, 1992), chpt. 7; Steven Weinberg, *The Discovery of Subatomic Particles* (New York: W. H. Freeman & Co, 1990), 3, 6; Chen Ning Yang, *Elementary Particles: A Short History of Some Discoveries in Atomic Physics* (Princeton: Princeton University Press, 1962); Isobel Falconer, "Corpuscles, Electrons, and Cathode Rays: J. J. Thomson and the 'Discovery of the Electron'", *BJHS* 20 (1987), 241-276; Theodore Arabatzis, "Rethinking the 'Discovery' of the Electron" *Studies in the History and Philosophy of Modern Physics* 27B, 4 (Dec 1996), 405-436; Michael Chayut, "J. J. Thomson: The Discovery of the Electron and Chemists," *Annals of Science*, 48 6 (1991), 527-544; Nadia Robotti, "J. J. Thomson at the Cavendish Laboratory: The History of an Electric Charge Measurement," *Annals of Science* 52 (1995), 265-284; Russell McCormach, "H.A. Lorentz and the Electromagnetic View of Nature," *ISIS* 61, 209 (Winter 1970): 459-498.
150. The two were obviously not the same. Neils Bohr accounted for the puzzling fact that if one abided by Nagaoka's planetary model of 1903, the revolving electron would soon loose all its energy and collapse. Energy was actually emitted (or absorbed) only when electrons jumped from one level to another, thus accounting for the Balmer series spectra. Smith never mentions spectroscopy in his work, despite its fundamental role in the history of early atomic physics. (In 1900, Heinrich Kayser published a 800 page book, "Handubch der Spectroscopie", which would be followed by 5 more volumes, for a total of over 5,000 pages on the topic. Sommerfeld, referred to spectra lines as the "true atomic music of the spheres." Pais, 166.) It should also be noted that between 1900-1910 countless models of the atom were put forth.
151. Smith, 6, 10-13, 14.
152. The reader should not presume, however, that these were entirely couched in 'reasonable' scientific theory—the movement of meteorites, according to Smith, were affected by the negative and positive electromagnetic forces between them and the sun.

153. Smith, 15-18, 19.
154. Ibid., 21.
155. Bush was a policy maker who effectively raised the quality of science in the United States 'a thousand fold.' He helped give scientists what they lacked at the turn of the century: political power and influence. See Kevles, *The Physicists*, passim.
156. Medical anthropology, the most well developed anthropology of science, has led the way in addressing these methodological issues which are all too often ignored by the usually conservative historian of science. Unfortunately, the field of anthropology rejected a disciplinary split which seems to have hindered its growth as a more broadly defined topic. Historians of science who have tried to enter the field have done a rather poor job of it; not so for historians of medicine. The better treatments, as Traweek's, however entirely ignore the cognitive element; focusing as they do on human interactions, they are more sociologies than anthropologies. Yet works such as Horton's, although certainly important, do not themselves suggest new amenable venues of research for the historian. Robert K Merton, "Insiders and Outsiders: A Chapter in the Sociology of Knowledge," *The American Journal of Sociology* 78, 1 (July 1972), 9-47; Byron J. Good, *Medicine, Rationality, and experience: An anthropological perspective* (Cambridge: Cambridge University Press, 1994), passim.; Landy, David, ed. *Culture, Disease, and Healing: Studies in Medical Anthropology* (New York: Macmillan Publishing Co., 1977), passim; Sarah Franklin, "Science as Culture, Culture as Science," *Annual Review of Anthropology* 24 (1995), 163-84; Malcolm R. Crick, "Anthropology of Knowledge," *Annual Review of Anthropology* 11 (1982), 287-313; Michael Macdonald, "Anthropological perspectives on the history of science and medicine," in *Information Sources in the history of science and medicine*, Pietro Corsci and Pual Weindling, eds., (London: Butterworth Scientific, 1983), 61-80; Sandra Harding, "Is Science Multicultural? Challenges, Resources, Opportunities, Uncertainties," *Configurations* 2 (1994), 301-330; Sandra Harding, *Is Science Multicultural?: post colonialism, feminism, and epistemologies* (Bloomington, Ind: Indiana University Press, 1998); Sharon Traweek, *Beamtimes and Lifetimes: The World of High Energy Physics* (Cambridge, MA.: Harvard University Press, 1988); Robin Horton, "African Traditional Thought and Western Science," *Africa* 37 (1967), 50-70, 155-185; Robin Horton and Ruth Finnegan, eds. *Modes of Thought* (London: Faber

- and Faber, 1973); Yehuda Elkana, "A Programmatic Attempt at an Anthropology of Knowledge," in *Sciences and Cultures*, Everett Mendelsohn and Yehuda Elkana, eds. (Dordrecht, Holland: D. Reidel Publishers, 1981), 1-76.
157. Compare, for example, the various calls made in the historiographical review of "American Science" (U.S.) with the large number of works that have been published since then. By contrast, the growth of national scientific histories in Latin America has been very uneven—in quality and quantity. Yet the typical tendency of North Americans to coequal "America" with the U.S. is a highly ethnocentrist approach likely to hinder the synthetic treatment of the two regions. Sally Gregory Kohlstedt and Margarte W. Rossiter, *Historical Writing on American Science*, vol. 1, 2nd series, *Osiris* 1 (1985).
 158. This of course, depends on how one categorizes them, or, inversely, defines ones categories. Despite minor variations, the general picture will remain true.
 159. Jose K. Ducci, ed., *Ciencias Fisicas*, vol. 5, *Trabajos del Cuarto Congreso Cientifico (1.O Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910); D. Santiago Marin Vicuna, ed. Ingenieria. vols. 18-19, *Trabajos del Cuarto Congreso Cientifico (1.O Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910). A much greater percentage in mathematics volume was obviously dedicated to 'pure science', but the volume for chemistry showed strong preference for the practical. Ricardo Poenish, ed., *Matemáticas Puras y Aplicadas*, vol. 6, *Trabajos del cuarto Congreso Cientifico (1.O Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910); Belisario Diaz Ossa, ed., *Ciencia Quimicas*, vol. 4, *Trabajos del cuarto Congreso Cientifico (1.O Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910).
 160. Dr. Jose Ducci K., "Las nuevas teorías de los fenómenos físicos," in Ducci Op. cit (5), 86-97.
 161. Delegacion Chilena, *Chile ante el Congreso Cientifico Internacional American de Buenos Aires; Informes I Monografías, Congreso Cientifico Internacio-*

nal Americano, Buenos Aires, 1910 (Santiago de Chile: Imprenta Universitaria, 1911), ii.

162. The lack of specialization was usual. During the nineteenth century, intellectuals covered many different areas. The tendency was not restricted to Latin America but was common to the U.S. as well. The tendency, however, seems to have continued there for a longer period.
163. "Ducci, Jose Kallens," *Diccionario Historico Biografico y Bibliografico de Chile*, ed. V. Figueroa, vol. 2 (Santiago de Chile: Balse Ils & Co, 1928), 610-613.
164. Eduardo Poirier, *Reseña General del 4.º Congreso Científico, 1.º Pan-Americano*. (Santiago de Chile: Imp. Lit. y Enc. Barcelona, 1915), *passim*.
165. Victor Delfino, "Nueva Teoria de los fenomenos electricos," in Ducci, 130-133.
166. Mariano Gutierrez Lanza, "Puntos de vista dobre los terremotos," in Ducci., 156-9.
167. It is an interesting, but immediately unanswerable, question as to whether the Latin American physicists there present were able to detect the poor quality of that research or whether they actually believed the claims made by its exponent.
168. Arturo Munnich, "Un fenomeno observado por la fotografia en las nubes y de origen probablemente electrico," in Ducci., 127-129.
169. G. L. de Llergo, "Morfogenia: Ensayo sobre la generacion de las formas redondas de los cuerpos," in Ducci., 134-148.
170. D'Arcy Thompson, *On Growth and Form*, abridged. ed J. T. Bonner (Cambridge: Cambridge University Press, 1969). Haeckel would obviously be a similar figure.
171. Llerdo., 145.
172. Arturo Munnich, "Un fenomeno observado por la fotografia en las nubes y de origen probablemente electrico," in Ducci., 127-129.
173. Gutierrez., *op. cit* (8), 149-225.
174. Gutierrez, 225-6
175. *Ibid.*, 153.
176. *Ibid.*, 149-172.

177. Stephen G. Brush, "Nineteenth-Century Debates about the Inside of the Earth: Solid, Liquid, or Gas?" *Annals of Science* 36 (1970), 252, passim.
178. Augusto Salina Arayas, *La Ciencia en Chile y en Los Estado Unidos de NorteAmerica: Un Analisis Historico Comparado, 1776-1976* (Santiago de Chile: CONICYT, 1976); Jacques Gaillard, *Scientists in the Third World* (Lexington: University Press of Kentucky, 1991); Frank Safford, *The Ideal of the Practical: Colombia's Struggle to form a Technical Elite* (Austin: University of Texas Press, 1976); T. Braun, W. Gläznel, "A Topographical Approach to World Publication Output and Performance in the Sciences, 1981-1985," *Scientometrics* 19, 3-4 (1990), 159-165; A Schubert and T. Braun, "International Collaboration in the Sciences, 1981-1985," *Scientometrics* 19, 1-2 (1990), 3-10; A. Schubert, W. Gläznel, T. Braun, "Scientometric Data files: A Comprehensive set of Indicators on 2649 Journals and 96 countries in All Major Science Fields and Subfields, 1981-1985," *Scientometrics*, 16, 1-6 (1989), 3-478.
179. Helge Kraugh, *Quantum Generations: A History of Physics in the Twentieth Century* (Princeton, NJ: Princeton University Press, 1999). Kraugh makes this observation of early twentieth century physicists in contrast to modern day physics, i.e. Heisenberg. However, I think the same comment applied to late nineteenth century physics when compared on a much broader framework as to the diverse ways of approaching nature.
180. F. H. Hinsley, ed. *The New Cambridge Modern History*, (Cambridge: Cambridge University Press, 1970), vol. 11, *Material Progress and World-Wide Problems, 1870-1898*, Charles C. Giffirin, "The States of Latin America" chpt. 19, pp. 536-541
181. David A. Hounshell, *From the American System to Mass Production: The Development of Manufacturing Technology in the United States, 1800-1932* (Baltimore: Johns Hopkins University Press, 1984), passim.
182. It is clear, however, that Zegers had a tremendous influence in the spread of the most advanced physics in Chile. His articles in local media included: "Los progresos de la Electricidad i el descubrimiento del profesor Roentgen" (1897), "El radio [radium]" in *El Mercurio* (April 1904); and likely "Las ciencias fisicas i la radio-actividad," in the *Annales* (1906). Local authors who also discussed radioactivity included A.E. Salazar, who wrote on radium for *El Mercurio*, July 1903. The actual scientific work Zegers presented at the 1PASC, however, did not deal directly with radio-

- activity. He will be further discussed in the next chapter. Alberto Obrecht, "De la figura de los planetas," in Poenish., Op. cit(5), 138-145; F. Ristenpart, "Expedicion chilean a Mocoetá, Provincia de Corrientes (Argentina), Para la observacion del eclipse total de sol el 23 de diciembre de 1908" in Poenish., Op. cit(5), 187-189; Luis L. Zegers, "Ensayo industrial del cobre por electrolisis," in Ducci., Op. cit(5), 49-54; M. Lachaud, "Rapidez de translacion de las moleculas gaseosas," in Ducci., Op. cit(5), 117-126.
183. *Diccionario biografico de Chile* (Santiago, Chile: Soc. imp. y lit. Universo, 1936-); Luis Emilio Rojas, *Biografia cultural de Chile*, second ed. (Santiago de Chile: Gong, 1987); Mario Cespedes and Lelia Garreaud, *Gran diccionario de Chile: biografico-cultural*, 2a. ed. (Santiago, Chile : Importadora Alfa, 1988); Virgilio Figueroa, *Diccionario historico, biografico y bibliografico de Chile*, 5 vols. (Santiago de Chile, Establecimientos graficos "Balcells & co.", 1925-31)
 184. "Obrecht, Alberto," in *Diccionario Biografico de Extranjeros en Chile*, ed. Pedro Pablo Figueroa (Santiago de Chile: Imprenta Moderna, 1900), 163-4; "Obretch, Huber Alberto" in *Diccionario Historico Biografico y Bibliografico de Chile*, ed. V. Figueroa, vol. 5, (Santiago de Chile: Balse Ils & Co, 1928), 383; Arturo Adlunate Phillips, *Chile mira hacia las estrellas: pequena historia astronomica* (Santiago de Chile: Editora Nacional Gabriela Mistral, LTDA, 1975), 119-141.
 185. The author has been unable to gather much information on Ristenpart. The astronomer is mentioned neither in Chilean nor in German historical biographies. Note that his directorship was cut short by his suicide in 1913. The only listing for a "Ristenpart" appears to be his son, Eugen Karl Emile, born in 1873, who obtained his doctorate at the University of Berlin in 1896. Eugen was a chemist, who worked at the Knipscher & Maass Silk Dyein Company in Paterson, New Jersey, and later was a professor in Frankfurt. The dates of his birth more likely show that the elder Ristenpart was perhaps his father, who had been in his late forties when he traveled to Chile. "Ristenpart, Eugene Karl Emil" *J. C. Poggendorff's biographisch-literarisches Handwörterbuch für Mathematik, Astronomie, Physik mit Geophysik, Chemie, Kristallographie und verwandte Wissensgebiete*, vol. 6 (Berlin: Verlag Chemie, 1938), 2186; Ibid (1959), 781.
 186. Marcel Lachaud, "Procedimiento de extraccion y purificacion de la cocaina por medio del tetracoloruro de carbono" in Diaz Ossa, 240-1.

Note that cocaine does not have the same social meaning then as it does now where it is so associated with poverty, and violence. At the time, cocaine had been initially introduced for medical purposes by Carl Koller in the U.S. with the effect of revolutionizing eye operations as a local anesthesia used for all sorts of operations: spinal, dental, and so forth. Although cocaine use was common (e.g. in Coca-cola, at turn of century), its addictive effects not fully known, and its use did not become a widespread crisis until the 1920's. By W.W.II usage declined, only to resurge again in 1960's in its more well recognized form. Sherwin Nuland, *Doctors: The Biography of Medicine* (New York: Vintage Books, 1995); S. L. Sgan, "Therapeutical uses of cocaine: a historical review," *Pharos* 61, 1 (Winter 1998), 23-8; H. F. Wulf, "The Centennial of Spinal anesthesia," *Anesthesiology* 89, 2 (August 1998), 500-6; J. E. McAuley, "Carl Koller—the man and the drug," *Dental History* 11 (October 1985), 21-6; M. Leonard, "Carl Koller: Mankind's greatest benefactor? The story of local anesthesia," *Journal of Dental Research* 77, 4 (April 1998), 535-8; J. Jones, "The rise of the modern addict," *American Journal of Public Health* 8, 1 (Aug 1995), 1157-62; G. Dag, "Cocaine abuse in North America: a milestone in history," *Journal of Clinical Pharmacology* 33,4 (April 1993), 276-310.

187. Raúl Silva Castro, "Don Eduardo de la Barra y la pedagogia alemana" *Revista Chilea de Historia y Geografia* (1942), 208-235. In 1899, de la Barra also wrote, "Chile ¿para los alemanes o para los chilenos?" (*El Porvenir*). He charged that many German teachers seldom went to class, spent most time researching, and gave poor lectures due to their poor Spanish. He also argued that pedagogical changes should not be attributed solely to Germans—that liceos were in a process of increasing their science studies. "¿Por que atribuir entonces a la importacion germánica una reforma esencialmente chilena...? Asi son los demas meritos alemanes." Certainly, attacks should not be seen only in their terms in that German's seem to have caused the resentment as a result of their associative rather than their scientific behaviors. There is no doubt that the Germans improved Chilean science.
188. Patricio Rogers Figueroa, "La astronomia en Chile durante la segunda mitad del siglo XIX," *Revista Chilena de Historia y Geografia* 150 (1982), 47.

189. One might point out that German journals were simply more widely read and more important than local Chilean journals—obviously providing a strong incentive for Ristenpart's astronomical agenda. While the first journals were 'universal', the second were 'provincial'.
190. Karl Malsch, "La cooperacion de los alemanes en al ensenanza de la quimica i su participacion en el florecimiento de las industrias quimicas en Chile", in Sociedad Cientifica Alemana de Santiago, *Los Alemanes en Chile*, vol. 1 (Santiago de Chile: Imprenta Universitaria, 1910), 290-1; F. W. Ristenpart, "Astronomos alemanes en Chile," *ibid.*, 177-193; F. W. Ristenpart, "El Observatorio Astrononimco Nacional en 1910" in *Anales de la Universidad de Chile* 128, 69 (July-Aug 1911), 941-2, hereafter "AUC." F. W. Ristenpart, "Memoria sobre el funcionamiento del Observatorio Astrononimco Nacional durante 1911" *AUC* 130, 70 (1912), 427-452; see "Inhaltsverzeichnis zu Band I bis IV," *Verhandlungen des Deutschen Wissenschaftlichen Vereins* (Valparaiso: Imprenta del Universo de Guillermo Helfmann, June 1885-June 1902). Their strong ethnic identity and German nationalism were similar to those of German immigrants to Argentina. See Ronald C. Newton, *German Buenos Aires, 1900-1933: Social Change and Cultural Crisis* (Austin: University of Texas Press, 1977), chpt. 2.
191. Ignacio Domeyko, *Mis Viajes: Memorias de un exiliado*, vol. 1 (Santiago: Ediciones de la Universidad de Chile, 1978), 779-847; Diego Barros Arana, *El Doctor Don Rodolfo Amando Philippi: Su Vida I Sus Obras* (Santiago de Chile: Imprenta Cervantes, 1904), *passim*.
192. Ristenpart, "Astronomos alemanes", p.186.
193. Alberto Obrecht, *Memoria sobre el estado actual del Observatorio Nacional de Santiago i proyecto de Reorganizacion* (Santiago de Chile: Imprenta Nacional, 1890), 15. "Desde luego podria formar los astronos *chilenos* del porvenir i tambien podria prestar servicios importantes a algunas personas que se dedican mas especialmente a la jeografia, oficiales de la marina, e ingenieros jeografos."
194. Alberto Obrecht, *Anales del Observatorio Nacional de Santiago (Estracto): Coordinadas jeograficas de algunas ciudades de Chile* (Santiago de Chile: Imprenta Nacional, 1890); Alberto Obrecht, *Sobre el Sistema de Desarrollo mas Conveniente para Representar el Mapa de Chile* (Santiago de Chile: Imprenta Cervantes, 1893) ; Alberto Obrecht, *Dibujo Practico del Mapa*

de Chile (Santiago de Chile: Editorial Cervantes, 1895); A. Obrecht, *Determinacion de la Hora y de la latitud jeografica de un lugar por la observacion de los momentos en que las alturas de algunas estrellas son iguales* (Santiago de Chile: Soc. Imprenta y Litografia Universo, 1907); Alberto Obrecht, *Observaciones Astronomicas i Meteorolojicas Desde Enero de 1905 a Diciembre de 1908* (Santiago de Chile: Imprenta Cervantes, 1909); Alberto Obrecht, *Nuevas Tablas Náuticas* (Santiago de Chile: Imprenta Universitaria, 1918).

195. As seen from Chile's National Observatory on August 12, 1892.
in Alberto Obrecht, *Observaciones Astronomicas i Meteorolojicas; como se verá en Chile el eclipse de Sol de 16 de Abril de 1898; Aspectos de Marte Durante la oposicion de 1892* (Santiago de Chile: Imprenta Cervantes, 1893), 2.
196. Alberto Obrecht, "Velocidad de las corrientes engendradas por la marea en un canal proyectando entre el puerto de Llico y el lago Vichuquen," in Poenish, 48-57.
197. Where R is the median radius, I was the "pendiente del perfil longitudinal" of the canal, and k the coefficient of dimersion.
198. Alberto Obrecht, *Observaciones Astronomicas i Meteorolojicas; como se verá en Chile el eclipse de Sol de 16 de Abril de 1898; Aspectos de Marte Durante la oposicion de 1892* (Santiago de Chile: Imprenta Cervantes, 1898), 6.
199. Alberto Obrecht, *Observaciones Astronomicas i Meteorolojicas* (Santiago de Chile: Imprenta Cervantes, 1892), 4.
200. Obrecht presents the eclipses as they were seen from Santiago, full and partial, respectively on April and October 1893. Alberto Obrecht, *Observaciones Astronomicas i Meteorolojicas; como se verá en Chile el eclipse de Sol de 16 de Abril de 1898; Aspectos de Marte Durante la oposicion de 1892* (Santiago de Chile: Imprenta Cervantes, 1898), 20, 22.
201. F. Ristenpart, "Expedicion chilean a Mocreá", 188; F. Risenpart, "Informe general", in *Chile ante el Congreso Cientifico Internacional American de Buenos Aires; Informes I Monografias* (Santiago de Chile: Imprenta Universitaria, 1911), 25-35; Philip Chandler, "Clairaut's Critique of Newtonian Attraction: Some Insights into his Philosophy of Science," *Annals of Science* 32, 4 (1975), 369-378; Guido Tagliaferri and Pasquale

- Tucci, "Carlini and Plana on the Theory of the Moon and their Dispute with Laplace," *Annals of Science* 56, 3 (1999), 221-269.
202. Ristenpart is here describing those causes undermining astronomical rigor: atmospheric aberration and "refraccion de pasaje" In the latter, one had to multiply the result by 1.00028 to get accurate result! Ristenpart, *Clases*, 17-23.
 203. F. Risenpart, "Informe," in *Chile ante el Congreso Científico Internacional American de Buenos Aires; Informes I Monografías, Congreso Científico Internacional Americano, Buenos Aires, July 1910*. (Santiago de Chile: Imprenta Universitaria, 1911), 25-35.
 204. Ristenpart here was not entirely forthright. The Observatory did have a journal, but it seems to have gone out of print. A. Obrecht, *Anales del Observatorio Nacional de Santiago* (Santiago de Chile: Imprenta Nacional, 1890).
 205. F. W. Ristenpart, "El Observatorio Astrononimco Nacional en 1909" *AUC* 126 (July-dec 1910), 738-8, 744, 747, 750-1; F. W. Ristenpart, "El Observatorio Astrononimco Nacional en 1910" *AUC* 128, 69 (July-Aug 1911), 923, 931, 933, 937; Rosauero Castro, "Memoria" *AUC* 128, 69 (July-Aug 1911), 161-168; F. W. Ristenpart, "Memoria sobre el funcionamiento del Observatorio Astrononimco Nacional durante el ano 1911" *AUC* 130, 70 (1912), 427-452; Compare these reports to Obrecht's. Obrecht hoped for 16 employees. He decided that: 1) it was not cost effective to move the observatory, 2) rains were not that bad—measurements could be done before and after their movement. Observatories actually helped railroad service by providing the accurate hour throughout nation, 3) the Observatory gravely needed a 'rejilla' (diffraction grating) but did not get one. Obrecht seems to have asked only for 50,000 pesos to improve state of observatory. Alberto Obrecht, *Memoria sobre el estado actual*, 4-5, 7, 10, 12, 14-15, 18.
 206. Federico W. Ristenpart, *El Cometa Halley: Conferencia dada en el Salon Central de la Universidad de Chile, Lunes 25 de Abril de 1910* (Santiago de Chile: Soc. Imp. y Lit. Universo, 1910).
 207. Obrecht, *Curso*, 160, 172.
 208. Alberto Obrecht, *Curso de Matemáticas Superiores de la Seccion de Arquitectura Profesado en la Universidad de Santiago* (Santiago de Chile:

- Imprenta Cervantes, 1908); Friedrich Wilhelm Ristenpart, *Clases de Astronomia Profesadas en la Universidad de Santiago de Chile: Tercer Ano: Teoria de los instrumentos, Segunda Parte (Instrumento de Psajes, Circulo Vertical, Instrumento Acodillado* (Santiago de Chile: Imprenta Cervantes, 1912), vi, passim.
209. Wilhelm Ziegler, "Ideas generales sobre la ensenanza de la fisica en Chile," *AUC* 118 (Jan-June 1906), 1-19
 210. Obrecht gives special emphasis to ellipse, hyperbola and parabola, which have been so important in history of science. Stein, put it towards the end of the book, hidden in appendix (p971-981); but he is the exception to the rule. Mizrahi gives it own chapter (chpt. 12); Shenk (chpt. 10); Leithold (chpt. 10); Purcell (chpt. 12). Obrecht's text in relation to these is thus more similar than different. However, there is a slightly different emphasis. We do owe a lot to ellipse. Given length of Obrecht's book, 227pp, much greater percentage is dedicated to it: 23%. In modern text-books, percents are as follow: Purcell (4%); Leithold (6%); Shenk (4%); Mizrahi (3%). Abe Mizrahi and Michael Sullivan, *Calculus and Analytic Geometry*, 2nd ed. (Belmont, CA: Wadsworth Inc, 1986); Edwin Purcell and Dale Varberg, *Calculus with Analytic Geometry*, 5th ed (Englewood Cliffs, New Jersey: Prentice-Hall, Inc, 1987); Sherman K. Stein, *Calculus and Analytic Geometry* (New York: McGraw-Hill Book Co., 1973); Al Stein, *Calculus and Analytic Geometry*, 2nd ed. (Santa Monica, California: Goodyear Publishing, Inc., 1979); Louis Leithold, *The Calculus with Analytic Geometry*, 5th ed. (New York: Harper & Row Pub., 1986).
 211. Alberto Obrecht, "Algunas consideraciones sobre el termino medio" in Poenish Op. cit (5), 2-6; Alberto Obrecht, "Teoria de las mareas" in Poenish Op. cit. (5), 146-153.
 212. Stephen G. Brush, *The Kind of Motion We Call Heat: A History of the Kinetic Theory of Gases in the 19th Century* 2 vols., (Amsterdam: North-Holland Publishing Co, 1976); Friederich Hund, *The History of Quantum Theory*. transl. Gordon Reece (New York: Harper & Row, 1974); Rancis L. Friedman and Leo Sartori, *The Classical Atom*, (Reading, MA: Addison-Wesley Publishing Co, 1965); A. d'Abro, *The Rise of the New Physics: Its Mathematical and Physical Theories*, 2 vols., (New York: Dover Publications, 1951); Martin Goldstein and Inge F. Goldstein, *The Refrigerator and the Universe: Understanding the Laws of Entropy* (Cambridge: Harvard University Press, 1993); A. J. Kox, "H. A. Lorentz's Contributions to

- Kinetic Gas Theory,” *Annals of Science* 47 (1990), 591-606; David Cahan, “From Dust Figures to the Kinetic Theory of Gases: August Kundt and the Changing Nature of Experimental Physics in the 1860’s and 1870’s,” *Annals of Science* 47 (1990), 151-172; Pehna Maria Cardoso Dias, “Clausius and Maxwell: The Statistics of Molecular Collisions (1857-1862)” *Annals of Science* 51, 3 (1944), 249-262.
213. Alberto Obrecht, “De la figura” 138-145; Alberto Obrecht, *Nueva Teoria de la Figura de los Cuerpos Celestes* (Santiago de Chile: Imprenta, Litografia, i Encuadernacion Barcelona, 1914). Did he steal the 1914 model from the founder of plate tectonic theory? It is impossible to say, although certainly he would have given his work a great deal of support. These models were ‘in the air’, particularly in Germany. In 1910, Frank B Taylor had alluded to continental drift, but did not fully develop theory; he was mainly concerned with creation of mountains in mid-Atlantic Ridge. Although Wegner’s book did not appear until 1915, his first paper on continental drift, under similar title, appeared in 1912 in *Geologische Rundschau*. see Martin Schwarzbach, *Alfred Wegner: The Father of Continental Drift* (Madison, Wisconsin: Science Tech Inc, 1986), chpts. 2-3.
214. Obrecht, “De la figura”, 139, 141, 145. For a review of experimental measurements and figures consult Arthur D. Butterfield, *A History of the Determination of the Figure of the Earth from Arc Measurements* (Worcester, MA: The Davis Press, 1906); James R. Smith, *From Plane to Spheroid: Determining the Figure of the Earth from 3000 B.C. to the 18th Century Lapland and Peruvian Survey Expeditions* (Rancho Cardova, CA: Landmark Enterprises, 1986).
215. “Clairaut” *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie, vols. 3-4, (New York: Scribner, 1970), 281-286; Charles Coulston Gillispie, *Science and Polity in France at the end of the old regime* (Princeton, NJ: Princeton University Press, 1980), 112-113; Antonio Lafuente and Antonio J. Delgado, *La geometricazion de la tierra: Observaciones y resultados de la Expedicion Geodesica* (Madrid: Consejo Superior de Investigaciones Cientificas, 1984); Frank D. Stacey, *Physics of the Earth* (New York: John Wiley & Son, 1969) 21, 25, 47; George D. Garland, *Introduction to Geophysics: Mantle, Core, and Crust* (Philadelphia: W. B. Saunders Co, 1971), chpt. 11; J. A. Jacobs, R. D. Russell, J. Tuzo Wilson, *Physics and Geology* (New York: McGraw-Hill Book & co, 1959), appendix B, “Clairaut’s Theorem” (p387-389); I. Todhunter, *A History of the*

Mathematical Theories of Attraction and The Figure of the Earth From the time of Newton to that of Laplace, reprint 1873, (New York: Dover Publications, Inc., 1873), 83-93, 189-231.

216. Todhunter, I, 229, 201.

217. Clairaut's treatment was much more thorough, consisting of 304 pages of formulation and exposition. While Clairaut dealt mainly with the figure of the Earth, Obrecht's was a more general formula that applied to other planets. Perhaps more importantly,

218. Todhunter, I, 389, 392.

D'Alembert's "fundamental equation" was

$$f(m) = (w^2/2\pi) - (M/2\pi h^2)$$

where w = angular velocity of rotations

h = distance from center of ellipsoid

M = mass of body

which also meant that, under certain conditions,

$$w^2/2\pi = 3M/2\pi h^3$$

which converts to equal

$$w^2 h^3 / 3M.$$

219. While most studies show how this was particularly true of the natural historian, we can observe that they equally applied to the theoretical physicist. Lucille Brockway, *Science and Colonial Expansion: The Role of the British Royal Botanic Gardens* (New York: Academic Press, 1979); Susan Sheets-Pyenson, *Cathedrals of Science: The Development of Colonial Natural History Museums during the Late Nineteenth Century* (Montreal: McGill-Queens University Press, 1988); Daniel R. Headrick, *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940* (New York: Oxford University Press, 1988).

220. We might also account for this on a certain stubbornness and vanity by Obrecht, but this explanation does not really fit his character. Obrecht had the full respect and admiration of his Chilean peers, and would not have needed further psychological 'reinforcement'.

221. In contrast to the specialized elitism of science, the parity of information in the humanities generally means that there will be more competitors for any given topic—and thus the greater probability of a rebuttal.

222. Lachaud, "Rapidez," 117.

223. John W. Servos, *Physical Chemistry from Ostwald to Pauling: The Making of a Science in America* (Princeton, NJ: Princeton University Press, 1990), 22-23.
224. Ibid., 120-122.
225. Where K = translational energy, H = total energy of gas molecules, and γ = ratio of the specific heats of gases. The first formula is Clausius's.
226. Ibid., 117-118.
227. Emilio Segrè, *From Falling Bodies to Radio Waves: Classical Physicists and Their Discoveries* (New York: W. H. Freeman and Co, 1984), 217-9. The pages include a very lengthy quote of Joule's. Edward I. Davis, "Waterston, Rankine, and Clausius on the Kinetic Theory of Gases," *ISIS* 61 (1970), 105-6; David Cahan, "From Dust Figures to the Kinetic Theory of Gases: August Kundt and the Changing Nature of Experimental Physics in the 1860's and 1870's," *Annals of Science* 47 (1990), 151-172.
228. Stephen Toulmin and June Goodfield, *The Architecture of Matter* (New York: Harper and Rowe, 1962), chpts. 11, 12; Aaron J. Ihde, *The Development of Modern Chemistry* (New York: Harper and Rowe, 1964), chpts. 15, 20; William H. Brock, *The Norton History of Chemistry* (New York: W. W. Norton, 1992), chpt. 10; Charlton, D.G. *Positivist Thought in France during the Second Empire* (Oxford: Clarendon Press, 1959), chpt. 1; John Stuart Mill, *Auguste Comte and Positivism*. reprint (Ann Arbor: University of Michigan Press, 1961); Lucien Levy-Bruhl. *History of Modern Philosophy in France*. reprint, (Chicago: Open Court Publishing Co, 1924) 352-4; John Theodore Merz. *A History of European Thought in the Nineteenth Century*. 4 vols., (New York: Dover Publishing Co., 1965), 182-3.
229. S. Chandrasekhar, *Truth and Beauty: Aesthetics and Motivations in Science* (Chicago: The University of Chicago Press, 1987). Einstein's well known 'God does not play dice' alluded to this principle.
230. Ibid.
231. Louis de Broglie, *The Revolution in Physics: A Non-mathematical Survey of Quanta*, transl. Ralph W. Niemeyer (New York: Noonday Press, 1953), 119-121, 301; Abraham Pais, 'Subtle is the Lord...': *The Science and the Life of Albert Einstein* (Oxford: Clarendon Press, 1982), 389-401.

232. This design is almost identical to Thomson's. Oddly, Ziegler never mentions his 'colleague's' work. Wilh. Ziegler, "Aplicaciones del tubo de rayos catodicos de Wehnelt," *AUC* 143 (Jan-Feb 1919), 77-91; Luis Zegers, "Las ciencias físicas i la radio-actividad," *AUC* 119 (July-dec, 1906).
233. A. Tafelmacher, "Sobre El Teorema de Fermat" *AUC* 82 (Nov-Apr 1892-1893), 415-437; Luis L. Zegers, "Los Progresos de la electricidad i el descubrimiento del Profesor Roentgen," *AUC* 98 (July-Dec 1897), 881-904; Cárlos Wargny, "Historia de las matemáticas" *AUC* 121 (july-dec1907); unknown, "Las ciencias físicas i la radio-actividad," *AUC* 119 (July-dec, 1906), 35-61; Wilh. Ziegler, "Aplicaciones del tubo de rayos catodicos de Wehnelt," *AUC* 143 (Jan-Feb 1919), 77-91; Don Ernie Döll, "Discurso de incorporacion a la Facultad de Ciencias Físicas i Matemáticas de la Universidad de Chile" *AUC* 146, 78 (jan-feb 1920), 3-43.
234. In their various reports, Obrecht, Ristenpart, Curtis, and a number of Germans, all complained about the poor state of mathematics in Chile. Patricio Martens, "La Física en Chile", in *Las actividades de investigacion y desarrollo en Chile: una vision de la comunidad científica nacional*, ed. Igor Saavedra, and Haime Lavados Montes, (Santiago: Ediciones CPU, 1981), 27-33; Igor Saavedra, "Antecedentes acerca de la historia de la física en Chile" *Boletín de la Academia Chilena de la Historia* 49, 93 (1982), 219-232. These two are the more reliable authors of the field, and are primary sources of sorts. Saavedra had participated in many of these changes.
235. Augusto Knudsen, "Fundacion de la energetica racional por la deducccion de la ecuaciones kineticas de Newton de principios energeticos puros," in Poenish, 190-199; Salina Arayas, *passim*; Charles A. Hale, *The Transformation of Liberalism in Nineteenth Century Mexico* (Princeton: Princeton University Press, 1989) *passim*.
236. It is not hard to imagine such business-oriented complaints in today's North American universities.
237. Philip C. Jessup, *Elihu Root* (New York: Dodd, Mead and Co., 1938), 288.
238. Spanish colonial parasitism was severely attacked by many Chileans during the nineteenth century, some more accurately than others. Jose V. Lastarria, "Investigaciones sobre la influencia social de la conquista i del sistema colonial de los Espanoles en Chile," in *Obras Completas Alejandro Fuenzalida Grandon*, ed., vol. 7, (Santiago, Chile: Litografia i Encuader-

- nacion Barcelona, 1906); Francisco Bilbao. *La America en Peligro* reprint (Santiago de Chile: Ediciones Ercilla, 1941); Simon Lipp, *Three Chilean Thinkers: Francisco Bilbao, Valentin Letelier, and Enrique Molina* (Waterloo, Canada: McGill University, 1975); Francisco Jose Moreno, *Legitimacy and Stability in Latin America: A study of Chilean Political Culture* (New York: New York University Press, 1969).
239. Sound waves measured using cathode ray tube in Chile, ca 1919. Wilh. Ziegler, "Aplicaciones del tubo de rayos catodicos de Wehnelt," *AUC* 143 (Jan-Feb 1919), 77-91; Luis L. Zegers, "Los Progresos de la electricidad i el descubrimiento del Profesor Roentgen," *AUC* 98 (July-Dec 1897), 881-904.
 240. The increasing power of the German state as a result of her drastic scientific-technological advancement since the mid nineteenth century was making itself increasingly felt in the world. This national strength likely also affected their reactions toward Chile—a relatively small peripheral state.
 241. This raises the interesting question of historical causality. Many unique and particular reasons can be found to account for each of the nations that did not participate. Does this mean there will be the same kinds of factors for all of them, or will there be highly different for each case? It is hard to say given the current state of historical research.
 242. Kraugh, op. cit.(19).
 243. If the life of Ramon y Cajal, a Nobel-prized physician, provides any indication of the general state of Spanish science, only the most persistent who practiced in the most primitive of sciences could possibly contribute to our sum total knowledge base. Otherwise, it would have been nearly impossible; they neither received the intellectual and financial support needed for such work. Dorothy F. Cannon, *Explorer of the Human Brain: The Life of Santiago Ramon y Cajal, 1852-1934* (New York: Henry Schuman, 1949)
 244. J. W. Herivel, "Aspects of French Theoretical Physics in the Nineteenth Century," *British Journal for the History of Science* 3, 10 (1966), 109-132; G Guiliani and P. Marazzini, "The Italian Physics Community and the Crisis of Classical Physics: New Radiations, Quanta, and Relativity (1896-1925), *Annals of Science* 51, 4 (1994), 355-390; M. Valera, "La fisica en Espana durante el primer tercio del siglo XX," *Llull* 5 (1983),

- 149-173; Luis Alfredo Baratas dias, Joaquin Fernandez Perez, "La ensenanza universitaria de las ciencias naturales durante la Restauracion y su reforma en los primeros anos del Siglo XX," *Llull* 15 (1992), 7-34; Carlos Lopez Fernandez, "Análisis temático de la producción en física recogida en los Anales de la Real Sociedad Española de Física y Química durante el periodo (1940-1975)," *Llull* 9 (1986), 105-126; Carlos Lopez Fernandez and Manuel Valera Candel, "Estudio Bibliométrico-multivariante de los artículos de física publicados en los Anales de la Real Sociedad Española de Física y Química durante el Periodo Franquista (1940-1975)," *Llull* 6 (1983), 37-56; R. W. Home, "The Beginnings of an Australian Physics Community," in *Scientific Colonialism: A Cross-Cultural Comparison*, Reingold, Nathan and Marc Rothberg, eds. (Washington DC: Smithsonian Institution Press, 1987), 3-34; Richard A Jarrell, "Differential National Development and Science in the Nineteenth Century: The Problems of Quebec and Ireland," in *Ibid.*, 323-350; J. Todd, "Science at the Periphery: An Interpretation of Australian Scientific and Technological Dependency and Development Prior to 1914: *Annals of Science* 50, 1 (1993), 33-58; R. W. Home, "The Problem of Intellectual Isolation in Scientific Life: W. H. Bragg and the Australian Scientific Community, 1886-1909," *Historical Records of Australian Science* 6 (1985), *passim*.
245. Aparajito Basu, "Chemical Research in India, 1876-1918" *Annals of Science* 52 6 (1995), 591-600; Satpal Sangwan, "Indian Response to European Science and Technology, 1757-1857" *BJHS* 21 (1988), 211-232; David Wright, "John Fryer and the Shanghai Polytechnic: making a space for science in nineteenth-century China," *BJHS* 29 (1996), 1-16; S. Irfan Habib and Dhruv Raina, "The Introduction of Scientific Rationality into India: A Study of Master Ramachandra—Urdu Journalist, Mathematician and Educationalist," *Annals of Science* 46, 6 (1989), 597-610; Gyan Prakash, *Another Reason: Science and the Imagination of Modern India* (Princeton, NJ: Princeton University Press, 1999).
246. Manuel A. Delano and Roberto Oehlmann, "Probables causas que han originado la explosion de los polvorines de Batuco, in Belisario Diaz Ossa, ed., *Ciencia Químicas*, vol 4, *Trabajos del cuarto Congreso Científico (1.º Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910), 184-197.
247. Brian Loveman, *Chile: The Legacy of Hispanic Capitalism* (New York: Oxford University Press, 1979). See below for further description.

248. Ibid.
249. Belisario Diaz Ossa, ed., *Ciencia Quimicas*, vol 4, *Trabajos del cuarto Congreso Cientifico (1.O Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910).
250. Ronald Bruce St. John, *Boundaries, Trade, and Seaports: Power Politics in the Atacama Desert*, Program in Latin American Studies, Occasional Paper Series no 28 (Amherst: University of Massachusetts, 1992), 2-3.
251. For analysis of regional land conflicts, in particular southern with Argentina, see the following. Ernesto Greve, *Barros Arana y la cuestion de limites entre Chile y Argentina* (Santiago de Chile: Ediciones de los Anales de la Universidad de Chile, 1958); James L. Garrett, "the Beagle Channel: Confrontation and Negotiation in the Southern Cone" *Journal of Interamerican Studies and World Affairs* 27,3 (Fall 1985), 81-110; Richard O. Perry, "Argentina and Chile: The Struggle for Patagonia, 1843-1881," *The Americas* 36, 3 (January 1980), 347-363; Jordi Marti-Henneberg, "How Discussions Concerning the Chile-Argentina Boundary have Stimulated the Study of Andean Glaciers," *Quipu* 6, 3 (Sept-Dec 1989), 331-338; Osiris G. Villegas, *El conflicto con Chile en la Region Austral* (Buenos Aires, Impreso Gráfica, 1978) ; Fernando Raul Saegner Castanos, *Cuestiones de limites entre Chile y Argentina: Los acuredos de 1991* (Santiago de Chile: Editorial Juridica Cono Sur Ltd, 1997).
252. Diana Kormos Barkan, *Walter Nernst and the Transition to Modern Physical Science* (Cambridge: Cambridge University Press, 1999).
253. The declining income from the Spanish government's 20% tax reflected overall decreases in production, going from 40,000 pesos in 1568 to 22,000 in 1583. The *situado* then had to be given by Spain to Chile in 1600 to help her fight against the Araucan Indians in the south. Loveman, 80.
254. During the gradual depletion of the nitrate resources, Chile would again also turn to copper.
255. Carmen Cariola and Osvaldo Sunkel, "The Growth of the Nitrate Industry and Socioeconomic Change 1880-1930," in *The Latin American Economies: Growth and Export Sector, 1880-1930*, Roberto Cortes and Shane J Hunt, eds., (New York: Holmes and Meier, 1985), 137-255; Michael

- Monteon, *Chile in the Nitrate Era: The Evolution of Economic Dependence, 1880-1930* (Madison: University of Wisconsin Press, 1982); Markos J. Mamalakis, *The Growth and Structure of the Chilean Economy: From Independence to Allende* (New Haven: Yale University Press, 1976), chpt. 8.
256. During 1850-1872, 10 M tons of guano shipped from one group of islands, netting \$20-30M per year. Guano often sold at \$80 a ton. Peruvian dependence on guano increased from 3% (1840) to 22.3% (1850), 69% (1870); actual revenues increased from 6,113 (1846) to 21,246 (1861), to a peak of 67,987 in 1872 (thousands of pesos/soles). It then declined to 22,500 by 1877. The guano age is recognized as spanning from 1848 to 1877. Shane J. Hunt, "Growth and Guano in Nineteenth-Century Peru," in Cortes., 299; William Jefferson Davis, *Tacna and Arica: An Account of the Chile-Peru Boundary Dispute and the Arbitrations by the United States*, reprint 1931 (New York: Archon Books, 1967), 26, 34.
 257. Davis, *passim*; Harold Blakemore, *British Nitrates and Chilean Politics, 1886-1896: Balmaceda and North* (London: Athlone Press, 1974); Ronald Bruce St. John, *Boundaries, Trade, and Seaports: Power Politics in the Atacama Desert* Program in Latin American Studies, Occasional Paper Series no 28 (University of Massachusetts, Amherst) 1992; Loveman, *passim*; see chapter one for references on U.S. diplomatic efforts.
 258. n.a. "Fertilizer" *Van Nostrand's Scientific Encyclopedia*, 6th ed. ed. Douglas M. Considine and Glenn D. Considine (New York: Van Nostrand, 1983), 1167-1171.
 259. The commonly espoused idea for a 'return' to the primitive tribal society is ludicrous. Without the modern chemical industry, there would literally be mass genocide worldwide.
 260. The study by Smil and others on Bosch and Haber's nitrogen fixation process had not been published by the time this book was finished. Vaclav Smil, *Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production* (Cambridge, MA: MIT Press, 2001); Dietrich Stoltzenberg, *Fritz Haber: Chemist, Nobel Laureate, German, Jew*, transl. Jenny Kein (Philadelphia, PA: Chemical Heritage Foundation, 2001). L. F. Haber, *The Chemical Industry, 1900-1930: International Growth and Technological Change* (Oxford: Clarendon Press, 1971); Isaac Asimov, *A Short History of Chemistry* (New York: Doubleday, 1965), 194-5; Jeffrey

- Allan Johnson, *The Kaiser's Chemists: Science and Modernization in Imperial Germany* (Chapel Hill: University of North Carolina Press, 1990).
261. Jimmy M. Skaggs, *The Great Guano Rush: Entrepreneurs and American Overseas Expansion* (New York: St. Martin's Griffin, 1994); Blakemore, *passim*;
 262. Luis Guglielmelli, "Contribucion al estudio de la imagen latente", in Diaz Ossa, 231-239; Carlos Malsch, "Conveniencia de adoptar metodos de ensaye y análisis uniformes en los casos litigiosos o de controversia: Creacion de un Comite Pan-Americano permanente, para el establecimiento official de estos metodos," in Diaz Ossa, 161-166.
 263. Belisario Diaz Ossa, "Electrolisis del Nitrato de Sodio," in Diaz Ossa, 213-225.
 264. *Ibid.*, 221, 222.
 265. Belisario Diaz Ossa, "Las mejoras realizadas en la industria salitrera", in Diaz Ossa, 179-183
 266. *Ibid.*, 180.
 267. Not unlike the sugar industry in Cuba at turn of the century.
 268. *Ibid.*, 181.
 269. Pablo Moriozot and Juan Rochefort P, "Estudio sobre la solubilidad del nitrato de sodio del cloruro de sodio y del sulfato de sodio en una mezcla de las tres sales," in Diaz Ossa, 226-230.
 270. *Ibid.*, 227.
 271. *Ibid.*, 228.
 272. Barkan, *passim*; John W. Servos, *Physical Chemistry from Ostwald to Pauling: The Making of a Science in America* (Princeton, NJ: Princeton University Press, 1990); M. B. Geiger, "Kenya Economic Feasibility of Caustic Soda Production for East Africa" in *Problems and Prospects of the Chemical Industries in the Less Developed Countries: Case Histories*, Nicky Beredjick, ed., (New York: American Chemical Society, 1970) 59-74.
 273. John Joseph Beer, *The Emergence of the German Dye Industry* (Urbana: University of Illinois Press, 1959); Ulrich Marsch, "Strategies for Success: Research Organization in German Chemical Companies and IG Farben until 1936," *History and Technology* 12, (1994), 23-77; *British Journal for*

- the History of Science*, special issue, "Organic Chemistry and High Technology, 1850-1950" 25, 84 (March 1992); Kathryn M. Olesko, ed., "Science in Germany: The Intersection of Institutional and Intellectual Issues," *Osiris*, 2nd ser, 5 (1898); Graham D. Taylor and Patricia E. Sudnik, *Du Pont and the International Chemical Industry* (Boston: G. K. Hall & Co., 1984).
274. Lincoln Gordon, *A New Deal for Latin America* (Cambridge: Harvard University Press, 1963), *passim*.
 275. The first time actual synthetic ammonia was ever produced had been in 1843 in France by Henri Victor Regnault. Morris Goran, *The Story of Fritz Haber* (Norman: University of Oklahoma Press, 1967); F. Aftalion, *A History of the International Chemical Industry* (Philadelphia, University of Pennsylvania Press, 1991), 86; Hugo Bauer, *A History of Chemistry*, transl. R. V. Stanford, (London: Edward Arnold, 1907), chpt. 3; William H. Brock, *The Norton History of Chemistry* (New York: W. W. Norton, 1992), chpt. 10; F. J. Moore, *A History of Chemistry* (New York: McGraw-Hill Book Co., Inc, 1918), chpt. 18-20; Aaron J. Ihde, *The Development of Modern Chemistry* (New York: Harper and Rowe, 1964), chpt. 15, 20.
 276. William S. Dutton, *Du Pont: One Hundred and Forty years* (New York: Charles Scribner's Sons, 1942), 338.
 277. Iron oxide is now used for process, obviously much cheaper and more readily available than uranium.
 278. Akira Kudo, "Japanese Technology Absorption of the Haber-Bosch Method: The Case of the Taki Fertilizer Works," in *The Transfer of International Technology: Europe, Japan and the USA in the Twentieth Century*, David J. Jeremy, ed., (Aldershot, England: Edward Elgar Pub., 1992); Takashi Hikino, Tsutomu Harada, Yoshido Tokuhisa, and James Yoshida, "The Japanese Puzzle" in *Chemicals and Long-Term Economic Growth: Insights from the Chemical Industry*, Ashish Arora, Ralph Landau and Nathan Rosenberg, eds., (New York: John Wiley & Sons, Inc., 1998), 116, 128.
 279. Raymond Ewell, "World survey of fertilizer production, consumption, and international trade" in *Fertilizer Production, Technology and Use: Papers presented at the Un Interregional Seminar on the Production of Fertilizers, Aug 24-Sept 11 1965* United Nations, (New York: UN, 1968), 1-

- 19; Goran 52; Stephen Black, "The sulphur, phosphorus, nitrogen, and chlor-alkali industries," in Alan Heaton, ed., *The Chemical Industry*, 2nd ed (London: Blackie Academic & Professional, 1994), 190.
280. B. Mostofi, "Problems and Prospects of the Chemical Industries in Iran," in *Problems and Prospects of the Chemical Industries in the Less Developed Countries: Case Histories*, Nicky Beredjick, ed., (New York: American Chemical Society, 1970), 34-46
281. United Nations, *Fertilizer supplies for developing countries: issues in the transfer and development of technology* (New York: UN, 1985), 15; Juan Carniglia Montesanto, "The fertilizer industry in Chile: actual conditions and future plans with regard to nitrogen, phosphate, and potash fertilizers" in *Fertilizer Production, Technology and Use: Papers presented at the Un Interregional Seminar on the Production of Fertilizers, Aug 24-Sept 11 1965* United Nations, (New York: UN, 1968), 74-80; United Nations, *Fertilizer Demand and Supply Projections to 1980 for South America, Mexico, and Central America* (New York: UN, 1971), 24; Frank B. Notestein, "South America other than Caribbean," in *World Geography of Petroleum*, ed. Wallace E Pratt and Dorothy Good (Princeton: Princeton University Press, 1950), 127; Naciones Unidas, *El Uso de Fertilizantes en America Latina* (New York: United Nations, 1966).
282. Carlos E. Monroe, "Un computo estadistico de los usos del nitrato de sodio en los Estados Unidos," in Diaz Ossa, 125-7
283. Ibid., 127.
284. William Kent, "La economia del combustible," in Diaz Ossa, 167-178.
285. Blakemore, passim; Loveman, passim; Monteon, passim.
286. Goran, chpt. 4.
287. Johan Schot, "Technology in Decline: a search for useful concepts; The case f the Dutch madder industry in the nineteenth century," *BJHS*, 25, 84 (March 1992), 5-26; Nathan Rosenberg, *Exploring the Black Box: Technology, economics, and history* (New York: Cambridge University Press, 1994).
288. F. P. Philippi, "Descripcion de Alguans Rocas del Desierto de Atacama," *AUC* 113 (1903), 141-; Victor M. Vargas, "Algunas observaciones sobre el Poryecto deCodigo de Minería presentado al Director de la Sociedad Nacional de Minería," *AUC* 113 (1903), 541-; Jullian Gustavo, "Esplota-

- cion i beneficio del salitre i iodo" *AUC* (1888), 381-; Manuel A Prieto, "Esplotacion i beneficio del salitre i iodo," *AUC* (1888), 317-; Luis Parapsky, "Las zeolitas del a coleccion mineralogicas del Museo Nacional," *AUC* (1888), 155-; Roberto Pohlman, "Noticias petrograficas del Llaguihe," *AUC* 84 (1893), 1247-; Roberto Pohlman, "Observaciones sobre la minerologia i jeologias de las islas Juan Fernandez," *AUC* 87 (1894), 633; C Martin, "La erupcion del vocan Calbuco," *AUC* 91 (1895), 161-; Federico Philippi, "La formacion carbonifera en Chile," *AUC* 101 (1898), 367-.
289. A. Haller, "Poyecto de creacion de un Institute de Quimica en al Facultad de Ciencias en Paris (Traduccion)," *AUC*, 128 (1911), 265-; P. Rossi, "La realidad molecular i la complejidad del atomo," *AUC*, 135 (1914), 317-; J. Brüggén, "La formacion de los carbones de piedra," *AUC* v.139 (1916), 659-.
290. It is likely that this competition stimulated Haber to his discoveries, a man who like Einstein lacked significant academic credentials. Jeffrey A. Johnson, "Academic, Proletarian...Professional? Shaping Professionalization for German Industrial Chemists, 1887-1920" in *German Professions, 1800-1950* Geoffrey Cocks and Konrad H. Jarausch, eds., (New York: Oxford University Press, 1990), 123-142; Johann Peter Murmann and Ralph Landau, "On the Making of Competitive Advantage: The Development of the Chemical Industries of Britain and Germany Since 1850", in *Chemicals and Long-Term Economic Growth: Insights from the Chemical Industry*, Ashish Arora, Ralph Landau and Nathan Rosenberg, eds., (New York: John Wiley & Sons, Inc., 1998), 27-75; Micheline Horstmeyer, "The Industry Evolves within a Political, Social, and Public Policy Content: A brief look at Britain, Germany, Japan and the United States," in *Ibid.*, 233-264.
291. The Escuela Practica de Minería at Copiapo had 46 students, Serena 56, and Santiago 69. More significantly, the Laboratorio Químico de Iquique had 18 students. By contrast, there were 410 students enrolled in the Conservatorio Nacional de Música. Labarra, 216-7.
292. It was not actually eliminated but rather reduced to a three year course of study.

293. Amanda Labarca H., *Historia de la Enseñanza en Chile* (Santiago de Chile: Imprenta Universitaria, 1939), 247, 278, 250, 205, 216-7; Poirier, *Chile en 1908*, 234.
294. Goran, 19; Karl Malsch, "La cooperacion de los alemanes en al ensenanza de la quimica i su participacion en el florecimiento de las industrias quimicas en Chile"; in *Los Alemanes en Chile*, ed. Sociedad Cientifica Alemana de Santiago, vol 1 (Santiago de Chile: Imprenta Universitaria, 1910), 287-302; Ignacio Domeyko, *Mis Viajes: Memorias de Un Exiliado*, vol. 1 (Santiago: Ediciones de la Universidad de Chile, 1978), 779-847; Manuel Martinez M.; Eduardo J. Delgado; Renato Sariego B, *AREA TEMÁTICA: QUIMICA* (Santiago de Chile: CONYCIT, 2000), 1-3.
295. Daniel Kevles, "The Physics, Mathematics, and Chemistry Communities: A Comparative Analysis" in Alexandra Oleson and John Voss, eds., *The Organization of knowledge in Modern America, 1890-1920* (Baltimore: Johns Hopkins University Press, 1979), 144, 152; John Lankford, *American Astronomy, Community, Careers, and power, 1859-1940* (Chicago: University of Chicago Press, 1997), chpt. 11; David A. Hounshell and John Kenly Smith Jr., *Science and Corporate Strategy: Du Pont R&D, 1902-1980* (Cambridge: Cambridge University Press, 1988); Kathryn Steen, "Wartime Catalyst and Postwar Reaction: The Making of the U.S. Synthetic Organic Chemicals Industry, 1910-1930." PhD thesis, University of Delaware, August 1995.
296. Markos J. Mamalakis, *The Growth and Structure of the Chilean Economy: From Independence to Allende* (New Haven: Yale University Press, 1976), 145-6; Loveman, chpt. 4.
297. Paul Gootenberg, *Imagining Development: Economic Ideas in Peru's "Fictitious Prosperity" of Guano, 1840-1880* (Berkeley: University of California Press, 1993); Shane J. Hunt, "Growth and Guano in Nineteenth-Century Peru" in Cortes, 255-319.
298. Blakemore, 72; Cariola and Sunkel, 207.
299. Labarra, 229, 210, 215, 233, 239.
300. The British community was small but seems to have integrated itself at a social level, through marriage. The community in Chile grew from 1,000 (1824) to 4,000, of whom 1,900 lived in Valparaíso; 1875 census showed 4,627 individuals. Some said that Valparaíso was "nothing more than an

English colony." For a review of British influence in Latin America as a whole see Bethell. Cariola and Sunkel, 154, 200; Blakemore, 11, 12; Leslie Bethell, "Britain and Latin America in historical perspective", in *Britain and Latin America: a changing relationship* Victor Bulmer-Thomas, ed., (Cambridge: Cambridge University Press, 1989), 1-24.

301. Valdivia seems to have been as much German as it was British. Both sides claimed it as its own.
302. Malsch, 290-302.
303. As Chilean historian Anibal Pinto characterizes it, there lacked a will to modernize, with most investments going into commodities rather than heavy machinery. For example, in 1883, while 22.7 million pesos went to such entities as clothing and wines, only 12.5 million went to machinery and telegraphs; in 1907 the numbers were 6 million to 3.78 million. The tragedy lies in that the technological sophistication needed was low, and would have had multiplier effects had Chileans done otherwise. Anibal Pinto Santa Cruz, *Chile: un caso de desarrollo frustrado* (Santiago de Chile: Edicion Universitaria, 1973), chpt 4; Anibal Pinto Santa Cruz, *Tres Ensayos sobre Chile y America Latina* (Buenos Aires: Ediciones Solar, 1971), chpt. 2.
304. Jalan takes Paraguay as his cut-off point for large-small state division. It had 2,810 th population, 11,200 sq km arable land, and \$2,100M GNP: country size index of 0.796. Chile, by contrast, had a country size index of 4.38: 10,533th pop (10M), 58,280 arable area sq km, and \$13,160 M GNP. Thomas, however, classifies small nations as those below 5M, and large ones above 30M. Bimal Jalan, "Classification of Economies by Size," in *Problems and Policies in Small Economies*, B. Jalan, ed., (New York: St. Martin's Press, 1982), 39-49; Ian Thomas, "The Industrialization Experience of Small Economies" in Jalan., ed., 103-124.
305. The example of Cuba's sugar industry during the nineteenth century, however, raises some question about the validity of this conclusion. David Vital, *The Inequality of States: A Study of the Small Power in International Relations* (Oxford: Clarendon Press, 1967); William G. Demas, *The Economics of Development in Small Countries with Special Reference to the Caribbean* (Montreal: McGill University Press, 1965); Paul Kennedy, *The Rise and Fall of the Great Powers: Economic Change and Military Conflict from 1500 to 2000* (New York: Vintage Books, 1989); Manuel Moreno

- Fraginals, *The Sugar mill: The Socioeconomic Complex of Sugar in Cuba, 1760-1860*, transl. Cedric Belfrage (New York: Monthly Review Press, 1976).
306. Chris Freeman and Luc Soete, *The Economics of Industrial Innovation*, 3rd edition (Cambridge, MA: MIT Press, 1999), 90, 98, 229; Hounshell, 183-4.
 307. Subrata Ghatak, *Technology Transfer to Developing Countries: The Case of the Fertilizer Industry* (Greenwich, Connecticut: JAI Press Inc., 1981), 107; United Nations, *Fertilizer Industry*. no 6, UNIDO Monographs on Industrial development—Industrialization of Developing Countries: Problems and Prospects (New York: UN, 1969); United Nations, *Fertilizer supplies for developing countries: issues in the transfer and development of technology* (New York: UN, 1985), chpt. 3.
 308. Because technologies tended to be less sophisticated and smaller scale, the commodity's costs tended to be higher than those on the international market. Only by tariff protection could it afford to exist in the region.
 309. Hyung Sup Choi, "Prospects and Problems of the Petrochemical Industry in Korea," in *Problems and Prospects of the Chemical Industries in the Less Developed Countries: Case Histories*, Nicky Beredjick, ed., (New York: American Chemical Society, 1970), 3-14; J. M. Sundarsky, "The Integration of the Chemical Industry in Israel: Prospects and Problems", in *Ibid.*, 47-57; Rinaildo Schiffino, "Problems and Prospects of the Petrochemical Industries in Brazil" in *Ibid.*, 103.
 310. Mariluz Cortes and Peter Bocock, *North-South Technology Transfer: A Case Study of Petrochemicals in Latin America* (Baltimore: Johns Hopkins University Press, 1984), passim; Freeman, chpts. 10, 11.
 311. Seymour Martin Lipsett, "Values, Education, and Entrepreneurship," in *Elites in Latin America*, Seymour Martin Lipsett and Aldo Solari, eds. (London: Oxford University Press, 1967), 3-60; Safford, Introduction; Freeman
 312. Robert S. Hopkins, *Darwin's South America* (New York: John Day Co., 1969), passim; Winthrop R. Wright, *British-Owned Railways in Argentina: Their Effect on Economic Nationalism, 1854-1948* (Austin: University of Texas Press, 1974), passim.

313. Peter H. Smith, *Politics and Beef in Argentina: Patterns of Conflict and Change* (New York: Columbia University Press, 1969), 16, 33-8; Roberto Cortes Condes, "The Export Economy of Argentina, 1880-1920," in Cortes, 325, 327, 330, 334, 339, 344-5, 365, 373.
314. Clothes easily stain with dyes for these reasons. To get synthetic dyes the following chemicals were mixed: Perkin's mauve (purple)—aniline plus potassium dichromate (oxidizing agent); fuchsine (red)—pure aniline with stannic chloride; blue—aniline with aniline red. Anthony S. Travis, "Science's powerful companion: A. W. Hoffman's investigations of aniline red and its derivatives", *BJHS* 25 (1992), 27-44.
315. Gessner G. Hawley, *Small Wonder: The Story of Colloids* (New York: Alfred A Knopf, 1947), 113; Aaron J. Ihde, *The Development of Modern Chemistry* (New York: Harper and Rowe, 1964), 358; Aftalion, 38.
316. Dr. Enrique Herrero Ducloux and Prof. L. Herrero Ducloux, "Datos calorimetricos de Mantecas Argentinas," in Dias Ossa, 154-160; Dr. Martiniano Leguizamon, "Seda artificial a base de caseina," in Dias Ossa, 249-251; Dr. Martiniano Leguizamon, "Constantes fisicas y quimicas del aceite de madera de la China," in Dias Ossa, 254-255; Doctor Jorge Magnin, "Sobre alteracion de las harinas desinfectadas por el metodo Clayton," in Dias Ossa, 256-257.
317. Outes, *Universidad Nacional*, 30.
318. Horacio Damianovich y Luis Guglielmelli, "Contribucion al estudio de los albuminoides," in Dias Ossa, 279.
319. Ibid.
320. Sodium nitrite, NaNO_2 is not represented in the equation, but rather its by-product, nitrous acid, NHO_2 , which is obtained by mixing a solution of the nitrite with another acid. Nitrous acid is relatively stable at room temperature, but will decompose to nitric acid, NHO_3 . It is curious to note that some of these reactions were similar to those used to obtain explosives such as TNT which can be made from a mixture of nitric acid with benzene and sulfuric acid.
321. The actual presentation is more complicated than the brief description given here. Since it is beyond the author's immediate purposes, a more detailed analysis will not be made.

322. This is perhaps not unlike those who argue that studies of computer hardware/software shed light on the workings of the human brain, which in contrast to Diamonovich's analogy, are more appropriate.
323. Horacio Damianovich, "Aplicaciones experimentales a la biología de la propiedades de las soluciones coloidales," in Dias Ossa, 283-291; Horacio Damianovich, "Influencia de las soluciones coloidales de materias colorantes sobre la germinación," in Dias Ossa, 292-296; Horacio Damianovich, "Acción de las soluciones coloidales de ciertas materias colorantes sobre los micro-organismos," in Dias Ossa, 296-298.
324. Trevor J. Pinch and Wiebe E. Bijker, "The social construction of facts and artifacts: or how the sociology of science and the sociology of technology might benefit each other," in Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch, eds., *The Social Construction of Technological Systems* (Cambridge, MA: MIT Press, 1987), 17-50; Trevor Pinch, "The social construction of technology: a review," in Robert Fox, ed., *Technological Change: Methods and Themes in the History of Technology* (Amsterdam: Harwood, 1986), 17-35; Robert Kline and Trevor Pinch, Users as agents of technological change: The social construction of the automobile in rural United States," *Technology and Culture* 37 (1996), 763-95
325. J. Stanley Clark, *The Oil Century: From Drake Well to the Conservation Era* (Norman: University of Oklahoma Press, 1958), 125-129; Naciones Unidas, *La Industria del Petróleo en América Latina: Notas sobre su Evolución Reciente y Perspectivas* (Nueva York: Naciones Unidas, 1973), 73; George Philip, *Oil and Politics in Latin America: Nationalist Movements and State Companies* (Cambridge: Cambridge University Press, 1982), 46-47.
326. Ernesto Longobardi, "Manifestaciones del petróleo en la República Argentina," in Diaz Ossa, 198-204.
327. "Some observers have expressed doubts as to whether this [Rivadavia] find really was accidental and there was certainly an air of mystery surrounding its immediate circumstances. Whatever the truth of the matter..." The author was unsure about the means used to detect these resources prior to our advanced electronic age. Philips, 162.
328. Herrero Ducloux, "Hidrología Agrícola e Industrial de la República Argentina," in Diaz Ossa, 5-38; Dr. Enrique Herrero Ducloux and Prof. L. Herrero Ducloux, "Las aguas minerales de los valles de Hualfín y otros de la provincia de Catamarca," in Diaz Ossa, 57-106; Doctor Jorge Mag-

nin, "Sobre un metodo de dosaje de sulfatos y de toda otra substancia precipitable, por emdio de las densidades; aplicable especialmetne a las que son de dificil filtracion," in Diaz Ossa, 246-248.

329. Longobardi wrote that, "En muchos puntos se puede ver como el petroleo gotea de las rocas bituminosas y se infiltra en otras capas que alternan con las calizas..." He also cited F Correa, "el petroleo aparece en forma de exudaciones en distintos puntos de la quebrada." Longobardi, 200.
330. Salta's roven reserves laid at 2.8 M cubic meters in 1967. U.N., *Industria Petrolera en America Latina*, 73.
331. Clarke, 129; Augusto Bunge, *La Guerra del Petroleo en la Argentina* (Buenos Aires: Imprenta La Rafica, 1937), 61-6; 98; Longobardi, 199;
332. Clark, ix.
333. Jonathan C. Brown, *Oil and Revolution in Mexico* (Berkeley: University of California Press, 1993), passim.
334. See discussion of in Introduction.
335. However we might judge such policies, it was clear that they had a favorable impact in that the diffusion of its citizens was nearly equal to a diffusion of modern science. Like the PASCs, this helped lay the scientific foundations of the country, although it did not seem to revolutionize the Chilean 'scientific mentality'. In this sense, both foreign influences, the United States and Germany, were complementary in Chile—particularly so when it is considered that the U.S. had borrowed its own models from the European nation.
336. It might be argued that the greatest beneficiaries of such exchange were not those at closest scientific parity with the United States but rather the more backward scientific nations. Ironically, it the close scientific ties Chile had to Germany that undermined the value of the exchange; such ideas were not quite as 'new' as they would be otherwise. As previously seen, many of these had been diffused in local journals by such German scientific expatriates as Luis Zegers or "Federico" Ristenpart. It might even be argued that since the US drew its scientific sources from Germany, such exchanges by the PASCs were merely second-hand when Chile had already been gaining such ideas directly from their source. This argument is somewhat of an oversimplification because in some scientific areas as astronomy, the US was an original producer, and in this sense

Curtis and Michelson's presentations should not be undermined. Whatever the case may be, the greatest beneficiaries from the PASCs were paradoxically not those who were about to enter a scientific 'take-off', but rather those that stood no chance to do so. Only to the most backward nation would these ideas have seemed entirely new given a possible lack of exposure—so new they might have seemed foreign. Even though they stood no chance of 'catching up', the congresses were useful at least because of the immediacy rendered to these leading research fields. At least an idea could be gained as to what type of race and challenges they were confronting.

337. The Argentinean participation at the 1PASC, on the other hand, showed that its chemistry seems to have already 'taken off' prior to the 1PASC. Their presentations in colloidal chemistry have that rather vivid trait of an intellectually energetic young discipline. The strong encouragement by the state, referred to by some as the second nation, had created a rather dynamic and intellectually self-engendering enterprise. Yet since its growth preceded the PASC, the congresses' influence in Argentina seems to have been relatively negligible and thus will not be discussed. Jose Babini, *Historia de la ciencia en la Argentina* (Buenos Aires: Ediciones Solar, 1986), chpt 3; Horacio H. Camacho, *Las ciencias naturales en la Universidad de Buenos Aires: Estudio historico* (Buenos Aires: Eudeba Editorial Universitaria de Buenos Aires, 1971), 77-85; Lewis Pyenson, *Cultural Imperialism and Exact Sciences: German Expansion Overseas, 1900-1930* (New York: Peter Lang, 1986), chpt 3. Babini actually characterizes first decade as one of 'decay', despite great flourishing in last third of previous century. However, it is clear that these advancements had their beneficial effect in the content of Argentinean chemistry, as seen in men like Diamanovich.
338. The scarcity of information does not provide enough evidence to aptly categorize him.
339. Australia's physics, however, was certainly stimulated by her economy, as Todd shows. Jan Todd, "Science at the Periphery: An Interpretation of Australian Scientific and Technological Dependency and Development Prior to 1914," *Annals of Science* 50, 1 (1993), 33-58.
340. The general economic stimulus of science could also be very clearly observed in the case of Argentina. While it might be argued that the theoretical was not emphasized in their research, it might be pointed out that

the majority of German chemical studies had also not been of a theoretical nature as well.

341. Inkster, *passim*.
342. Lewis Pyenson, "The Incomplete Transmission of a European Image: Physics at Greater Buenos Aires and Montreal, 1890-1920," *Proceedings of the American Philosophical Society* 2, 122 (April 1978), 92-114. This is a valuable article, and the similarities between the two countries are great. Focusing mainly on educational institutions, Pyenson showed how an early physics program established in 1909, peaked around 1913, but soon thereafter floundered. The causes for its slow beginnings were: lack of a valuation of basic science, inversely an overemphasis on the applied, poor funding, poor job prospects, physics defined as 'engineering' rather than pure research. Germans who traveled saw it only as temporary positions, had formed numerous 'German-centered' scientific organizations. Despite initial surge of activity, the field would not really begin until W.W.II when the Argentine Physical Society was formed. As in Chile, chemists fared much better than physicists. Although Pyenson raises the suggestive ideas, he does not fully explore these in his later books—"One theme concerns whether, and if so to what extent, economic factors may accelerate or retard the institutionalization of physics." (p. 114) in *Cultural Imperialism and Exact Sciences* he implies that the field was a 'non-economic' endeavor, suggesting a number of difficulties of such an approach with regard to physics. (p. xiii) Although the stimulus might be there, it is not as clear cut and obvious to prove or show as it is with regard to chemistry.
343. Paolo Palladino and Michael Worboys, "Critiques and Contentions: Science and Imperialism," *Isis* 84 (1993), 91-102. Pyenson's three-axis model is not a 'model' at all but mainly factors to consider in analysis. Like Basalla, it does not provide a mechanism for such an exchange. Lewis Pyenson, "Pure Learning and Political Economy: Science and European Expansion in the Age of Imperialism," in *New Trends in the History of Science: Proceeding of a conference held at the University of Utrecht*, R. P. W. Visser et. al., 274-278 (Amsterdam: Rodopi, 1989).
344. George Basalla, "The Spread of Western Science," *Science* 156 (1967), 611-622; Jorge Bartolucci, "Formacion tardia de las comunidades cientificas. El caso de los astrónomos mexicanos," *Quipu* (Sept-Dec 1991), 361-77; Roy MacLeod, "On Visiting the 'Moving Metropolis': Reflections on the Architecture of Imperial Science," in *Scientific Colonialism: A Cross-*

- Cultural Comparison.*, ed. Nathan Reingold and Marc Rothberg (Washington DC: Smithsonian Institution, 1987), 217-247; David Wade Chambers, "Period and Process in Colonial and National Science," in Reingold, 297-321; Ian Inkster, "Scientific Enterprise and the Colonial 'Model': Observations on Australian Experience in Historical Context," *Social Studies of Science* 15 (1985), 677-704; Rainald von Gizycki, "Centre and Periphery in the International Scientific Community: Germany, France and Great Britain in the 19th Century," *Minerva* 21 (1973), 474-494.
345. R.G.A. Dolby, "The Transmission of Science," *History of Science* 15 (1977), 1-43.
 346. Lynn White, *Medieval Technology and Social Change* (Oxford: Oxford University Press, 1962).
 347. Beer, 37; A. R. Hall, "Medicine and the Royal Society," in *Medicine in Seventeenth Century England: A symposium held at UCLA in honor of C. D. O'Malley*, ed. Allen G Debus, 153-174 (Berkeley: University of California Press, 1974). The important role of physicians in the rise and development of science does not seem to have been fully studied. As citizens with relatively higher social status and income living in societies where science has not yet gained state support, their functions seem to be crucial to its introduction. Again, the same was the case in Puerto Rico, but for slightly different reasons.
 348. Dr. Emilio R Conio, "Primer Congreso Científico Latino Americano," in *Anales de la Sociedad Científica Argentina* 83 (1917), 254.
 349. Segunda Reunion del Congreso Científico Latino Americano (Montevideo), *Parte I-Organización y Resultados Generales del Congreso* (Montevideo: Tip y Enc. Libro Ingles, 1901), 13-14, 55-70.
 350. The much larger 181-member committee had a total of 53 doctors, 44 lawyers, and 36 engineers. The scientific associations Venezuela sent to 3LASC included: La Universidad Central, La Academia Venezolana, Academia Nacional de la Historia, Universidad de los Andes, Universidad de Zulia, Colegio de Medicos, Colegio de Abogados, Colegio de Ingenieros, Escuela Nacional de Ingenieria. Dr. Antonio de Paula Freitas, ed., *Relatório Geral, Terceira Reunião do Congresso Científico Latino-Americano* (Rio de Janeiro: Imprensa Nacional, 1906), 56-72; 3LASC, *1o Boletim: Trabalhos Preparatórios ate 31 de dezembro de 1903, Terceira Reunião do Con-*

gresso Científico Latino-Americano (Rio de Janeiro: Imprensa Nacional, 1904), 37.

351. Eduardo Poirier, *Resena General del 4.º Congreso Científico (1.º Pan-Americano)* (Santiago de Chile: Imp. Lit. y Enc. Barcelona, 1915), 2-3.
352. The journal was surveyed randomly for years: 1900-1905, 1912, 1915, 1919, 1921, 1922, 1930. Surprisingly, the same traits appear between consecutive years, 1888-1899.
353. One would have been as correct by saying that there was as much of a chance to find a scientist amongst Chileans as it would have been to find a humanist amongst Germans; it generally did not happen in either case. Racist traits as skin color could not have been used as a causal factor because both sectors belonged to roughly the same racial phenotype, and in this sense Latin America was spared the extremist kind of derision that other nations faced where the racial-scientific lines were nearly congruent with each other. The more near technological-scientific proximity also meant that it was not as liable to the same kind of unequal relations as African nations experienced.
354. These numbers are similar to the United States today, and suggest a Latin Americanization of sorts. There has been a gradual decline in the number of science/engineering PhD's awarded to Anglo-Saxon North Americans, followed alongside by an increase in those awarded to foreign students who received 44% and 24% in engineering and science respectively in 1988. Although science degrees make up 30% of total undergraduate degrees in 1990, these figures are misleading because they include engineering—which was one of the most favored degrees at 28% followed by law at 10%. Those with actual intended career as a scientific researcher were at 6% in 1990. National Science Board, *Science and Engineering Indicators*, Tenth Edition (Washington DC, NSB, 1991), chpt 2; Task Force on Women, Minorities, and the Handicapped in Science and Technology, *Changing America: The New Face of Science and Engineering* (Washington DC: Task Force on Women, Minorities, and the Handicapped in Science and Technology, 1988), 32.
355. Again, a random sampling was done covering the following years: 1890-2, 1900-1904, 1919-1921.

356. Leo S Rowe, "The Pan-American Scientific Congress," *The American Review of Reviews* 39 (May 1909), 597, 600; see chpt 1 for references on LASCs.
357. 1PASC, *Segundo Boletín*, 19; 3LASC, *Relatório Geral*, 181-2.
358. Poirer, *Resena General*, 29, 37, 40; Poirer, Chile en 1908, 13. Lisoni had been a lawyer.
359. 2LASC, *Organización y resultados*, 83-100.
360. Antonio Ceriotti, "Enrique Herrero Ducloux," *Revista de la Facultad de Ciencias Químicas: Química y Farmacia* 8, 1(1933), 19.
361. 2LASC, *Organización y resultados*, 66-67. Italics by Cobos.
362. However, one needs to distinguish between the practice of science and the internal psychological motivation of the scientist. Obviously that Kepler or Newton were driven by quasi-magical emotional stimulus did not necessarily mean that they would necessarily do poor science. It is likely that, without the presence of strong economic incentives, science would ultimately have to be driven by this religious quest for truth in nature. It seems to have been rather typical of the time-period, and could obviously be observed in the U.S. as well. The *Monist* had been a leading journal with scientific articles. 2LASC, *Organización y resultados*, 65-70
363. Smith wrote that the nitrate industry, "bulked largely in the deliberations of the section." Woodworth noted that certain fields have not been studied at all, such as geomorphology and petrography. He also commented that Latin American nations have not established official organizations for study of mineral resources. *Report of the Delegates of the United States to the Pan American Scientific Congress, held at Santiago, Chile December 25, 1908 to January 5, 1909*. (Washington DC: U.S. GPO, 1909) 26, 33-37.
364. H. D. Curtis, "Astronomical Problems of the Southern Hemisphere," in *Matemáticas Puras y Aplicadas*, ed. Ricardo Poenish, vol 6, *Trabajos del cuarto Congreso Científico (1.º Pan-Americano celebrado en Santiago de Chile del 25 de diciembre de 1908)* (Santiago de Chile: Imp. Enc. y Lit. Barcelona, 1910), 154-164.
365. 3LASC, *Relatório Geral*, 188-203.
366. Sharon Traweek, "Kokusaika, Gaiatsu, and Bachigai: Japanese Physicist's Strategies for Moving into the International Political Economy of Sci-

ence,” in *Naked Science: Anthropological Inquiry into Boundaries, Power, and Knowledge*, ed. Laura Nader, (New York: Routledge, 1992), 174-201; Dolby, 16, 21, 23; Maurice Crosland, “History of Science in a National Context” *BJHS* 10, 35 (1977), 95-113

367. Poirer, *Resena General*, 55-58.
368. Again, the question arises as to our definitions. If one views physical chemistry mainly within physics, then one would make the argument that physics did successfully diffuse into the region; however, if we restrict our definition within chemistry, one would argue that it would not be. Such argumentation, however, seems to be rather trite.
369. 2LASC, organizacion y resultados, 204; Domingo Garibaldi, “Relaciones entre la densidad de algunos cuerpos liquido o solidos y su peso molecular y atomico con relacion al hidrogeno tomado como unidad.” in *ibid.*, 92.
370. *Chile ante el Congreso Internacional*, 62; 2LASC, *Organizacion y resultados*, 58-61; Aguinaga, 4; Outes, *La Universidad Nacional*, 30.
371. Outes had rather bitterly criticized the entry of the U.S., fearing that it would inhibit local participation because of its relative inferior state. He also attacked many European scholars who wrongly believed they had been the first to expose any such views without first consulting local studies. In other words, he argued that metropolitan scientists were unfairly ethnocentric, and did not give due recognition to local science. He was not the only one. Even Dr. Francisco Soca stated that the few scientific men created had been ignored by the centers of science; “isso permanencia ignorado nos centros de onde sahiam.” Augusto Vicuna, secretary or the 1PASC organizing committee believed that Latin America has held “false ideas that have kept us for nearly a century subject to an intellectual slavery in which Europe has dominated and influenced us with its laws, customs, history, and literature.” The comment is rather ironic in light that the aim was to advance a uniquely European worldview in the region (modern science).

The problem with this view, however, was that in order to ‘catch up’ one had to somehow be connected to these leading centers. Mere ‘reading’ was insufficient, and the quality of the personal contact did much to diffuse the spirit and manner in which the scientific enterprise was conducted. Outes, *La Universidad Nacional*, 41-6; 3LASC, *Relatorio Geral*, 196; Augusto Vicuna, “American and European Mentailty,” *Bulletin of the Inter-*

national Bureau of the American Republics (October 1908), 706; Dolby, 26-7.

372. When we compare this general feature of the PASCs to the development of science in Europe, we find a different development wherein a much narrower scientific definition was used. European scientists throughout the scientific revolution did not make such broadly aimed congresses or organizations—this selectivity appears to have been an important ingredient to the successful birth of modern science in Europe when seen comparatively. Seen in this light, Galileo's conflicts in his attempts to change the Catholic Church's dogma possibly might have done much more harm than benefit to the birth of modern science.
373. Adas, *Machines as the Measure of Men*, passim.
374. William H. McNeill, *The Rise of the West: A History of the Human Community* (Chicago: University of Chicago Press, 1991), 734.
375. One consequence of these historical dynamics is that the vastly more important underlying 'necessary causes' tend to be forgotten by North American scholars as Lawrence Harrison making cultural attacks. An undue emphasis is placed on the so-called 'failures' of Latin American culture, an obvious ethnocentric critique. Whether Latin America should seek the same goals and kind of society as that of North America is altogether a question not addressed by them—what is to be lost in the process? While certainly there are many material gains, cultural losses are entirely ignored. They blindly presume the virtue of North American society but fail to acknowledge either its many problems or the social costs of progress.
376. It should not be classified apart from the philosophical. Despite the ease it would render the armchair historian's task to do otherwise, too much should not be attributed to philosophers and philosophies as Bertrand Russell once wrote in his *History of Western Philosophy*.
377. Yet to presume otherwise would be also ironically ethnocentric as well—one wrong view understanding another mistaken one.
378. The opposite seems to be the case nowadays in the United States. There seems to be a shift from an emphasis on basic science to its application, while previously the focus had been on the foundational knowledge base of this technology, according to Vannevar Bush's scheme. This shift in

emphasis is perhaps suggestive of problems that the U.S. 'science industry' will face in the future.

379. Charles A. Hale, *The Transformation of Liberalism in Nineteenth Century Mexico* (Princeton: Princeton University Press, 1989); Augusto Salina Arayas, *La Ciencia en Chile y en Los Estado Unidos de Norte America: Un Analisis Historico Comparado (1776-1976)* (Santiago de Chile: CONICYT, 1976).
380. Stephen Lockhart Fogg, "Positivism in Chile and its Impact on Education, Development, and Economic Thought, 1870-1891." PhD. thesis., New York University, 1978., 41-4; Alejandro Fuenzalida Grandon, *Lastarria i su tiempo, 1817-1888: su vida, obras, e influencia en el desarrollo politico e intelectual de Chile*. vol. 2, (Santiago de Chile: Imprenta, Litografia i Encuadernacion Barceloa, 1911), 42-3; Julio G. Heise, *Historia de Chile, El Periodo Parlamentario, 1861-1925*. vol 1., (Santiago de Chile: Editorial Andres Bello, 1974), 146.
381. Alan J. Rocke, *The Quiet Revolution: Hermann Kolbe and the Science of Organic Chemistry* (Berkeley: Univeristy of California Press, 1993).
382. Nancy Stepan, *Beginnings of Brazilian Science: Oswaldo Cruz, Medical Research and Policy, 1890-1920* (NY: Science History Publications, 1981), Introduction.
383. It might even be said that North America's prior shortsighted individualist stance meant that she would have to suddenly make friends at a time of need, thereby raising serious doubts as to the genuiness of the intention. US participation also did not mean that they were scientific equals, far from it.
384. The ole of foreigners already living in Latin America suggests that the diplomatic function which Root hoped would be established by the congresses was somewhat curbed. Modern science did not diffuse to Chile via the PASCs or LASCs but rather via European émigrés; obviously, the previous existence of a scientific community was what had enabled the formation of scientific congresses in the first place. The *Anales* do show the continuous foreign influence necessary for the acquisition of science, and in this sense the PASCs were sufficient but not necessary factors in the process. We may also note that the PASCs value was certainly dictated by the perception of the relative importance of the information being dif-fused. The disparity of knowledge bases that the PASCs were trying to

bridge itself must have ironically served to undermine their efforts. As many US delegates complained, all too often Latin Americans failed to see the significance of the information being presented. Yet we may counter these observations by noting that because nations like Chile and Argentina with large German immigrants were the exception rather than the rule, genuinely new information and knowledge was being presented. In other words, the PASCs most likely had a favorable impact in establishing harmonious international relations between North and South America. To be appropriately answered, however, the issue obviously requires further research and analysis.

385. John W Servos, "Mathematics and the Physical Sciences in America, 1880-1930" *Isis*, 1986, 77: 611-629; National Science Board, *Science and Engineering Indicators*, Tenth Edition (Washington DC, NSB, 1991); Earl Smith and Joyce Tang, "Trends in Science and Engineering Doctorate Production, 1973-1990," *Who Will Do Science: Educating the Next Generation*, Willie Pearson, Jr. and Alan Fetcher, ed. (Baltimore: Johns Hopkins University Press, 1994), chpt. 6; Betty M. Vetter, "The Next Generation of Scientists and Engineers: Who's in the Pipeline," in *Who Will Do Science: Educating the Next Generation*, Willie Pearson, Jr. and Alan Fetcher, ed. (Baltimore: Johns Hopkins University Press, 1994), chpt. 1.
386. Jeffrey A. Johnson, "Academic, Proletarian...Professional? Shaping Professionalization for German Industrial Chemists, 1887-1920" in Geoffrey Cocks and Konrad H. Jarausch, eds., *German Professions, 1800-1950* (New York: Oxford University Press, 1990), passim; Fritz Ringer, "The German Academic Community", in Alexandra Oleson and John Voss, eds., *The Organization of knowledge in Modern America, 18960-1920* (Baltimore: Johns Hopkins University Press, 1979), passim; Lynn Nyhart, "Teaching Community via Biology in Wilhelmine Germany", Draft. in "Science and Civil Society" Conference, Madison, Wisconsin, April 13-16, 2000, passim; Fritz Stern, *Einstein's German World* (Princeton, NUJ: Princeton University Press, 1999), passim.
387. We may notice that even when Chileans were given the 'opportunity' to enter the nitrate business, they did not choose to do so but would wait more than half a century when the market was already in the process of becoming glutted. Even when one considers the inhibitory role of the German cartel, US aid might have remedied the difference.

388. John Stuart Mill, *Auguste Comte and Positivism*. Reprint, (Ann Arbor: University of Michigan Press, 1961); Andrew Abbott, *The System of the Professions: An Essay on the Division of Expert Labor* (Chicago: The University of Chicago Press, 1988). Ironically, Mill had been attacked by dependency theorists for supporting the national division of labor. His claims concerning positivism seem to have not been too widely considered.
389. Edwin T. Layton, "Mirror-Image Twins: The Communities of Science and Technology," *Technology and Culture* 12 (Oct. 1971), 562-580.
390. Philip Manson-Bahr, *Patrick Manson: the Father of Tropical Medicine* (London: Thomas Nelson and Sons Ltd, 1962); Jeffrey Allan Johnson, *The Kaiser's Chemists: Science and Modernization in Imperial Germany* (Chapel Hill: University of North Carolina Press, 1990); John W. Servos, *Physical Chemistry from Ostwald to Pauling: The Making of a Science in America* (Princeton, New Jersey: Princeton University Press, 1990).

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0-595-28424-8

The Pan-American Scientific Congresses ushered a new scientific era in Latin America. Bringing together scientists, engineers, and medical researchers from both South and North America, they facilitated the exchange of ideas between the two regions at the beginning of the twentieth century. Nobel Prize thinkers such as Albert Michelson and others, such as Franz Boas and Elmer Sperry, were some of the participants. The study describes the latest scientific advancements being diffused in these congresses, as well as the factors affecting the adoption of such advancements. Rodrigo Fernos teaches at the University of Puerto Rico (*Rio Piedras*).

Rodrigo Fernos studied at the University of Texas (Austin), Brandeis University, and the University of Minnesota (Minneapolis). He currently teaches at the University of Puerto Rico (*Rio Piedras*), and is director of the *Instituto de la Ciencia y Tecnología en América Latina* (www.ictal.org).

ISBN 0-595-28424-8



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