THE INTEGRATION OF PHONETICS AND PHONOLOGY

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ABSTRACT

For two millennia the phonetic sciences have been united in an attempt to understand the structure and behavior of speech. Questions and methods related to language history, speech pathology, and speech technology freely mixed. In the early 20th century a split developed between phonetics and phonology. In this paper I argue that the split was ill-conceived and based on a misapprehension of the aims and potential of phonetics (re-named "integrative phonology" here). None of the sub-disciplines in the phonetic sciences are on such a sure footing as to have the luxury of "going it alone." A reconciliation should be based on a frank admission that the great questions common to all the phonetic sciences remain unanswered and need a cooperative effort for their resolution.

1. INTRODUCTION

In the beginning there were no disciplines -- only people who asked questions and wondered about the make-up and workings of the universe, including the universe of speech: How did speech originate? What is the nature of speech? How are spoken words made different from each other? What is the origin of different languages or how does it happen that the "same" word is pronounced differently by different speakers or even by the same speaker in different contexts? How can one best learn another language? How can speech defects be corrected? How does sound come be associated with meaning? How can we control and extend the power of speech: evoke its sense with writing, transmit it over great distances, make inanimate objects respond to the spoken command? The biblical stories of Adam naming the beasts and the tower of Babel story are candidate answers to these implicit questions. The story of Ali Baba gaining access to the cave with the spoken command "open, sesame" reflects Man's desire to control machines using speech. The various writing systems of the world -- some having considerable antiquity -- testify to the ability of untutored people to analyze words into the sound elements that make them different.[1] Other cultures and other ancient texts offer different candidate answers to the same questions. Panini's grammar of Sanskrit, written some 25 centuries ago, gives answers to the question of what the nature of speech is; he specifies its articulatory correlates, a descriptive method we use to this day. Greek speculations on language dealt with the development of words and the association of sound and meaning.

How did the phonetic sciences develop from such questions and analyses? In this paper I propose to give not a formal history of the phonetic sciences but a few historical vignettes which will serve to remind us of some of the roots of our field and especially to shed some light on the emergence of phonetics and phonology as separate enterprises.

2. VIGNETTES FROM THE HISTORY OF THE PHONETIC SCIENCES

It is fascinating to discover the diverse origins of any field. Geology, for example, can trace its beginnings to biblical interpretations, the study of gems, minerals, and fossils, mining, cartography and astronomy, as well as traditional descriptions of the earth's surface by travellers. I doubt, though, that there can be few other fields with such a diversity of parent disciplines as the phonetic sciences. These include medicine covering also anatomy, physiology, and speech pathology; physics and engineering; zoology and ethology; language teaching; music and voice training; philology (the study of the history and interpretation of texts); grammar and rhetoric; psychology (including developmental studies); archeology and anthropology; stenography and spelling reform.

Ancient (and much modern) literature is filled with purely speculative answers to the above questions about speech. Some of these speculations are impressive for their ingenuity and occasionally for their congruence with modern findings (not that we should uncritically take that as a measure of success). But it is true in the phonetic sciences as in all others: many theories are offered, few receive empirical support. Significant advances require speculation coupled with supporting evidence.

Many of the notable early studies of speech were done by medical people because physicians were inclined to be empirical in their work, drawing conclusions based on direct experience with their patients. Unlike others, their livelihood depended on their being able to get results, not just elegantly turned arguments. As Galen, the 2nd century AD Greek physician and anatomist, remarked on questions of anatomy and physiology, Aristotelian philosophers preferred disputation to dissection [10].

Galen is perhaps the earliest "hands on" practitioner of the phonetic sciences known to us. Apparently on the basis of first-hand observations, he elucidated the respiratory element of speech and discovered the cerebral source of the recurrent nerve (the principal motor nerve of the larynx) which had previously been thought to come from the heart [60].

Among other notable medical people who made contributions to the phonetic sciences are the Italians Hieronymous Fabricius, also known as Fabricius ab Aquapendente, (ca. 1533-1619) [17] and his student Julio Casserio (ca. 1552-1616) [9]; the Englishman William Holder (1616-1698) [30]; the Swiss, Johann Conrad Amman (1669-1724) [1, 2] and Albrecht von Haller (1708-1777) [28]; the Germans Johannes Müller (1801-1858) [51], Emil Du Bois-Reymond (student of Müller; 1818-1896) [15], Hermann von Helmholtz (1821-1894) [29], and Ernst Brücke (1819-1892) [7][2]; the Czechs, Jan Purkyně (1787-1869)[3], Johann Nepomuk Czermak (1828-1873) [12]; the Frenchmen Denis Dodart (1634-1707) and Antoine Ferrein (1693-1769) [19]; the Dutch F. C. Donders (1818-1889) [14] and Hendrik Zwaardemaker (1857-1930) [83, 84].

Of these, Holder and Amman and the English mathematician John Wallis (1616-1703) were motivated in their study of speech by their attempts to teach the deaf to speak [1, 2, 30, 79].[4] Their pioneering works were quite influential for more than a century afterwards. Amman's work, which was translated into English, French, and German, exhibits some remarkably novel observations; for example, regarding the lateral "semi-vowel" [l], he notes [1] (pp. 52-53) that it

> is formed when the Tongue is so applied to the Roof, and the upper Teeth, that the Voice cannot, but by a small Thred, as it were, get forth by the Sides of the Tongue; for if

you compress the Cheeks to the Grinders, you stop up the Passage of the Voice, and it will be very difficult for you to pronounce this Letter,..."

This easily replicable do-it-yourself experiment demonstrates clearly the role of the buccal sulcus (the space between the cheeks and the molars) as a resonating cavity in speech (at least in some speakers). Amman is one of the first to attribute voice to the modulation imparted to the air stream passing through the glottis by the vibrations of the vocal cords [p. 29]. These vibrations he considered the 'substance' of speech; the 'form'[5] was imparted by "the various configurations of those hollow channels, thorough which they pass..." [p. 26]. This is one of the earliest and clearest expression of what we would now call the 'source - filter' model of speech. He also establishes an elementary binary, hierarchical classification of phonetic features which incorporates certain notions that might well be considered seriously by modern phonologists, e.g., that manner features dominate place of articulation features [p. 66]. He considered his system as a 'natural' hierarchical taxonomy and comments that substitutions of sounds (e.g., in pathological speech) involve similar sounds at the lowest strata of the hierarchy, not the highest, i.e., a dental 'semi-vowel' like l is substituted for another, r, or one nasal for another, i.e.., we don't see substitutions of vowels for consonants, etc. [pp. 66-67] It was also Amman (like Wallis before him) who made what might now be considered phonological observations: "If any word terminates in **n** and the following word begins with **b** or **p**, ... then in pronouncing the **n** we unconsciously change it, for the sake of euphony, into **m**, ..."

Amman was aware of the discrepancies between pronunciation and spelling but considered this primarily a fault of pronunciation. From our point of view this may be regarded as a confusion of spelling and sound but before we adopt a superior attitude, let us be sure we ourselves do not suffer from vestiges of the same confusion [57].

It was also a medical doctor, Christian Gottlieb Kratzenstein,[6] a German who lived and worked in Denmark, (1723-1795) who in 1780 was among the first to attempt the synthesis of speech and publish the results [37, 38].[7] Even though it concerned just isolated steady-state vowels, he did not yet have a clear idea of resonance, and his resonators bore little resemblance to the vocal tract (and thus didn't clarify how human vowels came about), he at least showed that mechanical synthesis of some speech sounds was possible.

It was, however, Wolfgang von Kempelen (1734-1804) a Hungarian engineer and a native of Vienna (part of the Austro-Hungarian Empire) who in 1791 [34] made one of the most influential pioneering contribution not only to speech synthesis but to phonetic science in general. His work *Mechanismus der menschlichen Sprache* gave complete blueprints (actually woodblock prints, and splendid ones at that) detailing the construction of a speaking machine [16]. It must be emphasized that it was not the speaking machine by itself which had such an impact on the field. Rather it was the combination of the machine plus the book he wrote describing it which had such great repercussions. His efforts represented a kind of step-function increase in the detailed attention given to all aspects of speech production. The book gives an impressive review of contemporary knowledge and speculation on speech and language. He discusses, among other things, animal communication, the sign language of the deaf, the origin of speech and language. He reviews the earlier work of Galen, Amman, van Helmont, Dodart, Ferrein, Haller, Herder, de Brosses, Court de Gebelin, Lord

Monboddo, Adelung, Abbé de l'Epée, and Kratzenstein. He gives a phonological comparison between languages, not only on their segment inventory but also with respect to their phonotactics (permissible clusters).

Erasmus Darwin (1731-1802), grandfather of Charles Darwin, a erudite, imaginative, and progressive "gentleman scientist" of the Enlightenment, dabbled in speech synthesis and constructed a mechanical synthesizer along the lines of von Kempelen although simpler in that it was capable only of labial sounds **p**, **b**, **m**, and the single vowel **a** ([13], pp. 119-120). In what must be one of the earliest proposed applications of phonetics to speech technology he suggested that his machine, "... if built in a gigantic form, might speak so loud as to command an army or instruct a crowd." In fact, this plan never would have worked because resonant frequencies are inversely proportional to the length of the vocal tract. A gigantic mouth would have had resonances so low and so close together (in frequency) that it is doubtful human ears could resolve them or recognize them as speech-like sounds. (However, it could have been possible in principle to make a speaking machine speak loud enough to address crowds by keeping the vocal tract the normal length but augmenting the lung force.) Darwin, although he was apparently not unaware of previous efforts by other writers, conducted his own analysis of the sounds of languages of the world and concluded that some 32 or 33 separate sounds might be recognized, including the Welsh **ll**. He also proposed that these sounds could be represented more simply by employing only 13 unary features which included the basic three places of articulation, oral resonance[8], nasal resonance, voiceless frication, voiced frication, etc. Since he found it difficult to determine the exact 'place of articulation' of vowels via kinesthesia, he devised a simple palatograph: "I rolled up some tin foil into cylinders about the size of my finger; and speaking the vowels separately through them [that is, inserting the cylinders into his mouth], found by the impressions made on them [that is, where they were dented], in what part of the mouth each of the vowels was formed...[p. 119]". This is one of the earliest instrumental phonetic studies performed on a live, intact, speaker.

One person seldom celebrated in the history of our field but who made several interesting contributions is the Englishman Thomas Young (1773-1829), also trained in medicine but who is most well known in the physical sciences for his demonstration of the wave nature of light. His minor dissertation written in Göttingen in 1795-1796 -- now lost -- was on the topic of universal phonetics: he proposed that all languages could be written phonetically using just 40 to 50 distinct letters. He was the first to decipher Egyptian hieroglyphics, a task completed for the most part by François Champollion. In an undeservedly-neglected paper of 1818, Young gave a mathematical account of the need to find several cognate words between languages in order to establish a family relationship. It is also to Young that we owe the coinage of the term 'Indo-European' (in a review of Adelung's *Mithradates*).

Robert Willis (1800-1875), a Cambridge professor of mechanics (engineering we would call it today) in his 1830 work "On the vowel sounds" [81] specified quantitatively the vocal tract resonances of vowels and claimed that the major determinant of vowels' characteristic acoustic patterns was vocal tract length. He also claimed that there were infinite vowel sounds and that one vowel faded gradually and imperceptibly into its neighbor in the series [i e a o u]. He remarked that with some refinement of his investigations he should be able

to provide "philologists with a correct measure for the shades of differences in the pronunciation of the vowels by different nations." Although his single resonance model of vowels is not supported today it is reminiscent of the notion that one can specify a single "characteristic" resonance of most vowels and that this is equivalent to a weighted average of F2 and F3 for front vowels and is approximately F2 for low and back vowels [18].[9]

One of the more interesting things about Willis' work is a subsequent, paper it inspired by T. Hewitt Key (1799-1875) first professor of Latin, then professor of comparative philology, at London University (now University College). Key, trained in medicine and mathematics (and a teacher of math at the newly formed University of Virginia from 1825 to 1827) contributed several papers to the Philological Society of London on various specific sound changes and sound change types. His paper "On vowel-assimilation, especially in relation to Professor Willis's experiment on vowel-sounds" appeared in the Transactions of the Philological Society for the year 1852 (but which was published in 1855) [35]. In this paper Key tries to explain vowel harmony and umlaut by invoking Willis' notion that vocal tract length is the main articulatory difference between vowels. This would not be judged a successful attempt in the light of current knowledge but let us not engage in what's called 'Whig' history (historical events judged according to modern standards and tastes): it is an admirable effort at applying the latest phonetic theories to phonological problems. It also has some memorable and still pertinent quotes:

> [some scholars of language] have allowed themselves .. to be led astray by paying more attention to the symbols of sound than to sounds themselves. ... Scholars seldom unite the love of classical and scientific pursuits; and a paper [i.e., Willis'] of the highest value for philology might well fail to meet with all the attention it deserved from the students of language, when published in a series of treatises [*Transactions of the Cambridge Philosophical Society*] almost exclusively of a mathematical character; not but that the paper has an indisputable claim to such a position, since it treats the problem with the accuracy of modern physics.

Hermann Grassmann (1809-1877), Sanskritist and the discoverer of the well known Greek and Sanskrit dissimilatory sound changes which are named after him [27], devoted most of his energies in his prime to mathematics, not to philology which was a pursuit in his later life. This hero of the comparative method and inspiration for the neo-grammarians, also made a significant (but now generally neglected) contribution to acoustic phonetics apparently being the first person to declare that some vowels had two distinct resonances, not just one as taught by Willis. He determined these resonances by purely auditory means by identifying the number (and thus the pitch) of the prominent harmonics of intoned vowels much as so-called harmonic singers can manipulate individual harmonics of their voice. This work was published in 1854 [26], nine years before Helmholtz published similar findings using instrumental means.

Another well known comparative philologist who saw no bar to integrating physical studies of speech with philology is Karl Verner (1846-1896], discoverer of the famous sound law that bears his name [77]. Verner's Law states that medial voiceless fricatives became voiced unless the accent fell on the preceding syllable. In his later years Verner was inter-

ested in trying to find out how and why accent could influence segments in this way. He constructed on his own an elaborate optical device which permitted him to enlarge the speech tracks on an Edison phonograph cylinder and to project them on the wall such that he could make hand tracings of them and then measure and analyze them. In essence he measured periods to derive the pitch and did a Fourier analysis of the signal. As it turned out, he didn't get any results he thought worth publishing. His research wasn't made public until after his death [21, 33, 78].

Abbé Pierre-Jean Rousselot (1846-1924), often called the father of experimental phonetics, continued to some extent the tradition of physiological studies of movement initiated by E. J. Marey, physician and pioneer in the study of locomotion and the one who perfected the kymograph (with his invention known as "Marey's capsule"). In general, it would not be inappropriate to say that Rousselot attempted to do for speech what Helmholtz attempted to do for vision and hearing, i.e., reduce their function to known physical physiological principles. Indicative of his view of the broad integrative character of the phonetic sciences are two of his major works, one, his dissertation [66] which was an attempt in part to give an instrumental phonetic account of the sound changes which shaped the dialect spoken in his home town, and, two, the application of phonetics to the problems of the deaf [67].

Even more than individual effort, what really demonstrates the existence of a continuing *tradition* mixing physics, physiology, and philology is the way that different authors built on the work of others, as in the case of T. Hewitt Key applying Robert Willis' theory of vowel production to vowel harmony. Many other examples of this exist including the following two.

Von Kempelen's work was widely known and extremely influential throughout the 19th century; it was cited in virtually every subsequent major work on voice and speech. Wilhelm Jacobi (1816-?) in his 1843 [31] work on the history of the German language attempted to give an account of German ablaut by a complex quasi-mathematical scheme based on von Kempelen's description of the articulation of various vowels. Other philologically-oriented writers incorporating the best contemporary phonetics into their philological work include H. E. Bindseil (1803-1876) [4], Karl Moritz Rapp (1803-1883) [63], Rudolf von Raumer (1815-1876) [64], and Friedrich Techmer (1843-1891) [74].

A further potentially far-reaching chain of influence from von Kempelen and Helmholtz to Alexander Graham Bell (1845-1922) is well known [22]. Crucial links in this chain were, first, Sir Charles Wheatstone (1802-1875) who demonstrated to the young Bell his replica of von Kempelen's machine and loaned him his copy of von Kempelen's book and, second, Alexander J. Ellis (1814-1890) who was a friend and associate of Alexander Melville Bell (1819-1905), Graham Bell's father. Ellis tried to explain to Alexander Graham and his older brother Melville how Helmholtz had discovered the principal resonances of vowels and synthesized them using tuning forks. Alexander Graham, while still a teenager, along with his brother, constructed a speech synthesizer roughly along the lines of von Kempelen's, although incorporating more realistic anatomical detail. This experience along with the extensive knowledge of articulatory phonetics that he learned from his father, author of the influential system of self-interpreting physiologically-based phonetic transcription [3], gave Graham Bell the confidence to think that it should be possible to break speech down into some simpler form

and transmit it across great distances. The rest, as they say, is history.

3. THE UNITY OF THE PHONETIC SCIENCES

What conclusion can be drawn from these snapshots from the early history of phonetic sciences? The conclusion I draw is that there had not yet been any hardening of the division of the phonetic sciences into largely separate sub-disciplines of phonetics and phonology and their applications in speech pathology and speech technology. Certainly those who studied speech pursued their research primarily in the way they were used to, depending on their background and training: medical, mathematical, physical, or philological, but with many interesting and enlightened excursions from one domain to another. There seemed to be a genuine belief in an idea that we tend to give only lip service to today: the underlying unity of all science--or at least of the phonetic sciences.

It is generally recognized that the separation of phonology and phonetics occurred as a result of the rise of structuralism, taught initially by Ferdinand de Saussure (1857-1913) and Jan Baudouin de Courtenay (1845-1929) but fully developed in phonology by the Prague School. N. S. Trubetzkoy (1890-1938) [75, 76], a leader of the Prague School, differentiated between "... the study of sound pertaining to the act of speech (phonetics) ... and the study of sound pertaining to the system of language (phonology)." Since the proper study of all of structural linguists was the system of language it followed from this (and is commonly believed today) that phonetics is not part of linguistics.[10] The emphasis on system or the relationship between speech sounds rather than on the substance of those sounds represented a new concern and one which seemed at the same time to open up new frontiers for phonological study and to liberate the study of speech sounds from physical phonetics and all the burdens of its natural sciences methods.

I admire and draw inspiration from the phonological work of Trubetzkoy and other phonologists in the tradition initiated by the Prague School. Indeed, some of Trubetzkoy's phonological generalizations were based on intuitive phonetic grounds (though he felt he had to apologize and explain at some length how this didn't imply that he thought precise phonetic correlates of sound contrasts mattered). But Trubetzkoy's conception of phonetics was something of a cartoon stereotype:

> La phonétique actuelle se propose d'étudier les facteurs matériels des sons de la parole humaine: soit les vibrations de l'air qui leur correspondent, soit les positions et les mouvements des organes qui les produisent. ... Le phonéticien est nécessairement atomiste ou individualiste ... Chaque son de la parole humaine ne peut être étudie qu'isolement, hors de tout rapport avec les autres sons de la même langue. ([75], pp. 232-233)

A similar stereotype applied to astronomy would characterize its proper activity as merely looking at and cataloguing stars. No mention would be made of cosmology, astrophysical theory, etc., i.e., attempts to generalize about the birth, development and death of stars, the formation of galaxies, the origin of the universe. This is the fallacy of equating the immediate, visible object of study to the ultimate object of study. Though the immediate object of study in phonetics (and in the psychological study of speech) may be the sounds and articulations of speech, the ultimate objects of study are the underlying causes of

speech sound behavior, where "behavior" includes the same broad domain that Johann Amman studied three centuries ago, how laterals are produced, the assimilation of nasals to the place of articulation of following stops, the patterns of substitution of one speech sound for another.[11]

A possible advantage of the split of phonology from phonetics was the freedom of the phonologist to address issues more of a psychological or functional than a strictly physical phonetic nature. Also, it was possible to bring in a host of new ostensibly non-phonetic factors as the causes of speech sound behavior, e.g., structural "pressure" (the existence or non-existence in the language of similar contrasts).

But to carry through with such a program it would have been necessary to embrace some of the methods and concepts of psychology or perhaps certain aspects of the theory of communication. Unfortunately this was not done. Rather phonology was practiced as if it were an autonomous discipline owing little or nothing to other scientific domains.

And it was not just the domain of inquiry that phonology left behind after its divorce from phonetics; it also abandoned phonetics' approach to argumentation, i.e., its manner of bringing evidence to bear on theoretical claims. Over the decades the phonetic sciences had established a respectable degree of *accountability* in the way that generalizations and theories were proposed and defended. If anything, the degree of accountability in the field has been improved and tightened since then. As a result there is a relatively continuous and cumulative tradition on which to develop and refine both methods and theories. To give just one example, and one which has far-reaching implications for phonology and for the behavioral sciences in general: careful phonetic studies spanning a century have demonstrated, the tremendous amount of variation -- essentially infinite in character -- that exists in the speech signal [55, 59].

In contrast, autonomous phonology has yet to develop a tradition of accountability: it has enlarged the list of causal factors which it can cite to account for given phonological behavior -- structural pressure; maintenance of equilibrium in the total phonological system; striving for simplicity, naturalness or unmarkedness, learnability, etc. (and this is a positive move) -- but it has not enlarged its repertory of ways to insure the *quality* of evidence offered in support of its claims. Actually, by abandoning phonetic methods and by not adopting those from psychology, it has depleted its methodological arsenal. Freed from what it regards as the confinement of an "empiricist and mechanistic" approach to speech sounds, it can not only propose a completely new range of theories but even those which contradict phonetic findings: voiceless sounds can be called voiced, nasalized vowels can be called oral, distinctively aspirated stops can be treated as redundantly aspirated, closed syllables can be called open. None of this is inherently bad; throughout the history of science, claims which seem to fly in the face of common sense have proven their worth, e.g., that matter consists primarily of empty space. Nevertheless, at some point this and all claims must impinge on the tangible world, even if indirectly, e.g., (to continue the preceding example) by showing that most subatomic particles pass through metal sheets without being deflected. However necessary and valuable simplicity and generality of individual claims are and the degree to which they fit into a larger self-consistent theoretical framework, these properties by themselves never substitute for empirical support. It is disap-

pointing is to see the almost complete disinterest of autonomous phonologists in the possible relevance for their claims of phonetic or psychological findings. For example, linguistics textbooks continue to characterize aspiration on /p t k/ in English as redundant and, to my knowledge, have never paid any attention to, or attempted to contradict, the evidence that aspiration is the principal auditory cue differentiating them from /b d g/ in initial position [44].

It may be objected that in spite of phonologists' statements about the difference between phonology and phonetics, there is a sense in which all phonological work in fact incorporates some phonetics insofar as it uses terms such as 'obstruent', 'voice', etc. However, I would like to differentiate between two forms of phonetics [56], one I call 'taxonomic' phonetics (for lack of a better term) and the other 'scientific' phonetics. Taxonomic phonetics has provided us with traditional phonetic terms and symbols used to describe and classify speech sounds and has remained essentially unchanged since the formation of the International Phonetic Association a century ago. Scientific phonetics, on the other hand, continues to change. It constantly expands its horizons; it develops new data, concepts, and methods; it rejects or revises earlier beliefs shown to be deficient, and, to the extent that these beliefs or theories have congruence with the universe, it has practical payoff, e.g., in language teaching, speech pathology, and speech technology. Of course, it also has payoff in phonology: how would we be able to make sense of the inherent tendency of obstruents towards voicelessness [54] if Husson's neurochronachtic theory of vocal cord vibration had not been effectively refuted. While autonomous phonology embraces taxonomic phonetics, for the most part it excludes scientific phonetics. A good bit of what is called and taught as "phonetics" in many universities -- if it is taught at all -- is exclusively taxonomic phonetics.

This is a pity because scientific phonetics is the intellectually most exciting form of the field--and one of the most successful and rigorous within linguistics (if one allows, of course, that it is part of linguistics). It addresses issues of fundamental importance for phonology: how sounds differ from each other [39, 44, 70, 71], how sounds vary thus leading to sound change [24, 54, 55]. It is even possible in many cases to give principled reasons why sounds change in one way but not in others. Insofar as the causes of change can be located in the physical phonetic domain, it calls into question the common practice of assigning change to the grammar [57, 59].

The development of divisions and specialized branches of scholarly disciplines is common enough in the history of science, e.g., the basic division between statistics and pure mathematics. This happens naturally as the body of knowledge and methods in one area becomes too large for individual practitioners to master. This happened with organic and inorganic chemistry. Splits also occur as new questions arise. This happened in nuclear and (classical) physics. But in examining the causes of the split of phonology and phonetics, I conclude that it was based on a complete misunderstanding of what was termed "phonetics": an inability to see the forest for the trees.

4. INTEGRATIVE PHONOLOGY

What of the body of scholarship that autonomous phonology split off from -- that body of work that was decreed not to be phonological and by some not even part of linguistics? What shall we call it? 'Phonetics'? No, it was and is

more than that. This tradition never really acquiesced to the claim that traditional phonological concerns -- to explain the behavior of speech sounds -- could or should be approached in an isolated, autonomous fashion. Therefore, I'll call it "integrative phonology". As I tried to argue and demonstrate, integrative phonology was accepted and practiced up to and throughout the 19th century. In spite of the supposed separation of phonetics and phonology triggered by the structuralist revolution, it was also practiced in this century by Zipf [82], Stetson [68, 69], Zwirner and Zwirner [85], Menzerath [48, 49], Grammont [25] -- to pick a few out of many such figures active in the first half of this century. In the last half of this century, we see the same principles in (and I must be forgiven for the brevity and unavoidable selectivity of the following list) Jakobson, Fant, and Halle's pivotal work, *Preliminaries to Speech Analysis* [32], in the work coming out of Haskins Laboratories [45] and the Pavlov Institute of Physiology [36] (especially the research on syllable structure), the Institute of Phonetics in Copenhagen [20], the work on speech sound universals by Ladefoged [39] and Maddieson [46], as well as contributions by Lehiste [40], Lindblom [41, 42, 43], Stevens [70, 71], Rossi [65], and Browman and Goldstein [6, 24].

Integrative phonology does not accept its proclaimed banishment from linguistics. It has not surrendered phonological questions to those who would pursue them in isolation of phonetics, psychology, and many other disciplines that can assist. In fact, in spite of Trubetzkoy's claim to the contrary, phonetics *has* developed methods and theories which address the functioning of speech sounds as elements of a system [41, 42, 44, 71]. The dividing line between phonetic, phonological, and psychological studies of speech sounds is quite blurred in much current research, e.g., that of Pisoni [61], Fowler [23], Massaro [47], Nearey [52, 53].

Integrative phonology does not solve problems by the unchecked proliferation of novel theoretical entities; rather, it attempts to keep the theoretical entities to a minimum and draws most of the building blocks of its theories from the realm of the previously established -- often that which has substantial empirical support. Its theories tend to contain within them an indication of how they could be tested and for the most part the first test is offered by the author of the theory.

I also think integrative phonologists have more fun with their research: they retain a kind of child-like curiosity about speech and like children often get their hands dirty and insert odd objects into their mouths and noses.

5. THE RECONCILIATION OF INTEGRATIVE AND AUTONOMOUS PHONOLOGY

The legacy of this divorce of autonomous phonology from integrative phonology six decades later is that a considerable gap has developed between them [11, 39]. An expression of this, perhaps inadvertent, is the frequently encountered collocation 'the interface between phonetics and phonology', where, as I have argued elsewhere [56], the term 'interface' incorrectly implies that the two disciplines are largely independent and autonomous. But if there is an apparent irreconcilable chasm between the two, even though both are trying to understand the same phenomenon, speech, we should entertain the possibility that one or both of them espouses unrealistic and indefensible positions. Perhaps there really isn't such an unbridgeable gap if we could just drop the extravagant claims. I make this proposal seriously: even astrology and astronomy could be reconciled if the empirically indefensible claims

made by one side or another could be thrown out.

To start such a rapprochement between the two approaches to phonology I suggest that both sides should admit to the things that they are really not sure about.

What does integrative phonology know and not know about speech? Considerable lore about speech has accumulated over the centuries which permit reasonably complete descriptions of particular instances of speech. As a result it is possible to do speech synthesis by rule and to some extent speaker-independent speech recognition based on feature extraction. In spite of these successes, however, it must be admitted that we do not yet have a truly general theory of speech production and perception. For example, although there is strong belief that there is *some* fundamental concatenative unit underlying speech there is not much agreement on what it is. Various proposals exist: the phoneme, the phone (the same size as the phoneme but drawn from a much larger set since there is no posited functional identity between all the phones), the diphone, the demisyllable, the syllable, etc. It is even possible that more than one of these units are operable at different stages of speech production and speech perception [58]. Shockingly, there is not even complete agreement on the acoustic-auditory correlates of vowel quality: most believe that formant frequencies matter but acknowledge that absolute formant frequencies can't be crucial since these vary between speakers and even within speakers between different contexts. Much research is being done on trying to discover higher-order relationships between the formants [50]. There is some evidence that time-varying formant frequencies are important cues to vowel quality [52, 53, 73], i.e., that vowels consist of a trajectory through the vowel space rather than static points. Some reject formant frequencies and advocate whole-spectrum measures [5]. Related to this is a much more fundamental dispute over whether there are any truly context-invariant phonetic correlates of linguistic distinctions as opposed to context-sensitive cues [43, 72]. There is also no clear consensus on the causes of universals in speech sound systems, although there is informed speculation on this topic [39, 41, 42, 43, 70, 72]. The list of disputed issues is quite large.

It might be thought that if integrative phonology is unsure about such fundamental points then clearly it is in a weak position vis-a-vis autonomous phonology. But I take the controversies as a sign of strength and honesty; it would be much worse if the community of integrative phonologists just gullibly accepted claims based on their superficial plausibility, mere internal consistency, or their fashionableness, rather than on the rigorously gathered evidence supporting them. In any case, it is premature to judge integrative phonology weak because it knows what it doesn't know; we have yet to hear the confessions of ignorance from the autonomous phonologists.

6. CONCLUSION

In the final analysis, I think it will be found that everyone in the phonetic sciences, including autonomous and integrative phonologists, know very little about the same thing: how speech is structured and how it works. In other words we ask the same questions -- in fact, much the same questions as have been asked throughout history. When the divided parties realize that neither one has all the answers, they can cooperate in trying to resolve their common questions.

7. NOTES

1. Further evidence of this skill comes from comparison or linking of words by their constituent sounds

through the use of such poetic devices as rhyme, alliteration, assonance, the construction of rhyme tables, and establishing a conventional order of the elements of an alphabet or syllabary.

2. In 1871 Brücke published a work on phonetic aspects of verse [8] which included measurements of lip movements obtained with a device of his own invention. These are among the first instrumental phonetic recordings.

3. Purkyně's phonetic work was done in the 1830's but only rediscovered and published in the 1970's [62].

4. An interest in teaching the deaf to speak also motivated in part the research of Wolfgang von Kempelen and Alexander Graham Bell.

5. 'Substance' and 'form' are, of course, elementary notions in Aristotelian metaphysics.

6. Kratzenstein was well known for, among other things, his promotion of electricity for therapeutic purposes and for his advocacy of the two-fluid theory of electricity (in opposition to his contemporary, Benjamin Franklin's, one-fluid theory).

7. Von Kempelen, however, had begun the construction of his speaking machine in 1769.

8. Darwin used slightly different terms; I am 'translating' his terminology into their approximate modern equivalents.

9. By an odd coincidence Willis had an encounter with von Kempelen-- though after the latter's death: Willis published an expose of von Kempelen's fake chess-playing automaton which was put on tour throughout Europe after the inventor's death [80].

10. In a widely disseminated directory of electronic mail addresses in North American and Europe, the header indicates that it lists the addresses of " ... linguists and a number of people in *related disciplines like phonetics* ..." [emphasis added].

11. There may have been some phoneticians who advocated a kind of extreme positivism, e.g., Scripture, but this was hardly characteristic of the whole sweep of the phonetic sciences in the early decades of this century and it certainly isn't true of phonetics today.

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