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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 are currently 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).

The goal of the split 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 the 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 to 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 animate 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.

Other cultures and other ancient texts offer different candidate answers to these questions. Panini's grammar of Sanskrit, written some 25 centuries ago, gives answers to the question of what the nature of speech is; and the 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. In doubt, though, that there can be few other fields with such a diversity of parent disciplines as the phonetic sciences. We 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); archaeology and anthropology; andrography 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 talismans 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 other medical professions, the livelihood depended on their being able to get results, not just elegantly turned arguments. As Galen, the 2nd century physician, said to an assistant, "When we are at the mercy of the gods, we are at the mercy of the tone of voice, and the sound of our voice is the same as the voice of others, just as the tone of the flute is the same as the tone of the voice, and the flute is kept by 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 Hieronymus Fabricius, also known as Fabricius ab Aquapendente (ca. 1533-1619) [17] and his student Giulio Cassersio (ca. 1552-1616) [19]; the Englishman William Holder (1616-1698) [30]; the Swiss, Johann Conrad Amman (1669-1724) [12]; [22] and Albrecht von Haller (1708-1777) [28]; the Germans Johannes Müller (1801-1858) [51], Emil Du Bois-Reymond (student of Müller; 1816-1896) [18], Hermann von Helmholtz (1821-1894) [29], and Ernst Brücke (1819-1892) [7]; the Czechs, Jan Purkyně (1787-1869), Johann Nepomuk Czermak (1828-1873) [32], the Swissmen Denis Diodart (1634-1707) and Antoine Ferrein (1693-1769) [19]; and the Dutch F. C. Donders (1818-1889) [14] and Hendrik Swammerdam (1687-1930) [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]. 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" [1], 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 throb, as it were, get forth by the sides of the tongue; for if
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Galen is perhaps the earliest "hands on" practitioner of the phonetic sciences known to us. Apparently on the basis of first-hand observations, he studied 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]

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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, ... and you will easily reproducible 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 modulations 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' was imparted by the various configurations of those hollow channels, through 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.

And he established an elementary binary, hierarchical classification of phonetic features which incorporates certain notions that might well be considered serendipitous by modern phonologists, e.g., that manner features dominate place of articulation features [p. 66]. He considered his 'system of hierarchically the length of the tautosyllabic tongue... I consider that man, and by... a natural hierarchical taxonomy and comments that substitutions of sounds (e.g., in a pathological speech) involve similar sounds at the lowest stratum of the hierarchy, not the highest, i.e., a dental vowel like ə is substituted for another, e.g., /t/. 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 m and the following word begins with b or p, then in pronouncing the m 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 are not victims of the same confusion..." [57].

It was also a medical doctor, Christian Gottfried Kratzenstein, a German who lived and worked in Denmark, (1772-1795) who in 1780 was among the first to attempt the synthesis of speech and publish the results ([37, 38]). 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 sound speech was possible.

It was, however, Wolfgang von Kempelen (1734-1804) a Hungarian engineer and native of Vienna (part of the Austro-Hungarian Empire) who in 1791 [34] made one of the most influential contributions to speech synthesis not only to speech synthesis but to phonetic science in general. His work Mechanismus der menschlichen Sprache (phonetically woodblock prints, and a splendid one at that) detailing the construction of a speaking machine [16]. It is clear that it was not the speaking machine by itself which had such an impact on the field. Rather it was the combination of temporary knowledge and speculation on speech and language. He discussed, among other things, animal communication, the sign language of the deaf, and the origin of speech and language. He reviews the earlier work of Galen, Amman, von Helmont, Dodart, Ferrein, Hailer, 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 (possible clusters). Charles Darwin (1750-1802), great-grandfather of Charles Darwin, a naturalist, imaginative, and progressive scientist of the Enlightenment, dabbled in speech synthesis and constructed a mechanical synthesizer along the lines of von Kempelen although 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 earlier 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 was doubtful that a human could recognize or recognize them as speech-like sounds. (However, it could have been possible in principle that an acoustic machine could be loud enough to address crowds by keeping the vocal tract the normal length but augmenting the lung force.) It was apparently not unaware of previous efforts by others 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 11. 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 and 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 through the foiled cylinders (that is, inserting the cylinders into his mouth), found by the impressions made on them (that is, where they were depressed) 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, and he worked at deciphering Egyptian hieroglyphics, a task completed for the most part by Francois Champollion. In an underserved-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. In his treatise he wrote that the coinage of the term 'Indo-European' (in a review of Adelung's Ethnographie, Robert Willis (1800-1875), a Cambridge professor of mechanics (engineering) would call it today) in his 1832 work 'On the vowel sounds' [81] specified quantitatively the main 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 the next. In the series [i e o u]. He remarked that with some refinement of his investigations he should be able
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,...''

Your experiment does 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 airstream passing through the glottis by the vibrations of the vocal cords [p. 29]. These vibrations he considered the 'substance' of speech; the 'form' 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.

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I rolled up some tin foil into cylinders about the size of my finger; and speaking through sepa- rately the vowels [i.e., inserting the cylinders into my mouth], found by the impressions made on them [i.e., whether they were depressed] 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.

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In an undervedingly-neglected paper of 1818, Young gave a mathematical account of the need to find several cognate words between languages in order to establish family relationships. He also noted that we owe the coinage of the term `indo-European,' in a review of Adlington's Mithradates, a Cambridge professor of mechanics (engineering we would call it today) in his 1837 work on the vocal tract of the human voice, he described the vocal tract resonances of vowels and claimed that the major determinant of vowel sounds was the vocal tract length. He also claimed that there were infinite vowel sounds and that one vowel faded gradually and imperceptibly into the next in the series [i e ou]. 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 a single resonance model of vowels is not supported today it is reminiscent of the notion that one can specify a single "characteristic" for each vowel of most vowels and that this is equivalent to a weighted average of F2 and F3 for front vowels and is approximately F2 for back vowels [18].

One of the more interesting things about Willis' work is a subsequent paper inspired by T. Hewitt Key (1799-1875), his first professor of Latin, then professor of comparative philology, at London University (now University College, London), trained in medicine and mathematics and a teacher of math at the newly formed University of Virginia from 1825 to 1827. It contributed several papers to the Philological Society of London specific sound changes and change type changes. His paper "Vowel- assimilation, explication, and explanation," in which he proposed "Willis' experiment on vowel-sounds" appeared in the Transactions of the Philological Society for the year 1852 (but which was published in 1865) [35]. In this paper Key tried to explain vowel harmony and un hiatus by invoking Willis' notion that vocal tract length is the main determining influence 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 a '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 paring more attention to the symbols of Robert 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 Philological Society] almost exclusively of a mathematical character; not but that the paper has an individuality which deserves 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 dissimulatory 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. He created a new method and inspiration for the neo-Grammarians, also a significant man (Professor 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 as the instrument-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). If 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 interested 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 so 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].

Abbe Pierre-Jean Rousselet (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, he was inappropriate to say that Rousselet attempted to do for speech what Helmholtz attempted to do for vision and hearing, i.e., unravel the function of their consonant physical physiological principles. Indicative of his view of the broad integrative character of the 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 the application of Robert 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 von Kempelen (1843) [31] work on the history of the German language attempted to give an account of German ablat by a complex quasi-mathematical scheme based on von Kempelen's description of the articulation of various vowels. Other philologically-oriented writers incorporated the best contemporary phonetics into their philological work including H. E. Bindekel (1803-1876) [4], Karl Moritz Rapp (1803-1883) [62], 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, the Charles Wheatstone (1802-1875) who demonstrated to the young Bell his replica of von Kempelen's automaton and placed him in the hands of von Kempelen's book and, second, Alexander J. Ellis (1814-1890) who was a friend and associate of Alexander Graham Bell (1819-1906). 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, 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, authored the influential 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
to provide "philologists with a correct measure for the shades of differences in the pronunciation of the vowels by different nations." Although the single resonance model of vowels is not supported today it is reminiscent of the notion that one can specify a single "characteristic" of most vowels, and that this is equivalent to a weighted average of F2 and F3 for front vowels and is approximately F2 for back vowels [18].

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and transmit it across great dis-
tances. The rest, as they say, is
history.

3. THE UNITY OF THE PHONETIC SCI-
ENCEs

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
application 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 excurs-
sions 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 (1849-1929) but fully
developed in phonology by the
Prague School (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 (pho-
nology)." Since the proper study of
all of structural linguistics 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
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 methodology 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 psycholo-
getic 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
correlates).

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 pressed into service 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 phonetic
approaches to argumentation, i.e.,
its manner of bringing evidence to
bear on theoretical claims. Over
the decades the phonetic sciences
have 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 development of 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
spans 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
repertoire 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 psycho-
ology, it has depleted its methodo-
logical arsenal. Freed from what
it regards as the constraints of an
"empiricist and mechanistic"
approach to speech sounds, it can
not only propose a completely new
range of theories of phonology in which conflict phonetic findings:
voiceless sounds can be called
voiced, nasalized vowels can be
called oral, differently stressed
stems can be treated as redundantly
aspirated, closed syllables can be
called open. None of this is inher-
ently 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 con-
tinue the preceding example) by
showing that most subatomic particles
pass through metal sheets without
being deflected. However neces-
sary and valuable simplicity
and generality of individual claims are
and the degree to which they fit
into a larger sense of the system.
A prerequisite for this framework, these properties
by themselves never substitute for
empirical support. It is disap-
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 application 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 sciences—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 of 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 linguistics was the system of language it followed from this (and is commonly believed today) that phonetics is not part of linguistics. The emphasis on 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 methodology of articulation of following stops, the patterns of substitution of one speech sound for another.

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 the so-called 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 perceived 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 approaches 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 body of work on which to develop and refine both methods and theories. To give just one example, and one which has far-reaching consequences 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 confines of an "empiricist and mechanistic" approach to speech sounds, it can not only propose a completely new range of theories of phonetics which contradict phonetic findings: voiceless sounds can be called voiced, nasalized vowels can be called oral, distinctively marked stops can be treated as redundantly aspirated, closed syllables can be called open. None of this is inherently bad; throughout the field 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., by providing the framework, e.g., by showing that most subatomic particles pass through metal sheets without being detected. However necessary and valuable simplicity and generality of individual claims are and the degree to which they fit into a larger self-consistent structure of the natural world, these properties by themselves never substitute for empirical support. It is disap-
pointing is to see the almost complete disinterest of autonomous phonology 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 has 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 accumulates 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 Huxley’s neurochronarchic theory of vocal cord vibration had not been eventually refuted. While autonomous phonology embraces taxonomic phonetics, for the most part it excludes scientific phonetics. A good bit of work 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, but the basic division between statistics and pure mathematics. This happens naturally as the body of knowledge and methods of inquiry becomes too large for individual practitioners to master. This happened with organic and inorganic chemistry, physics 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 deemed 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 acquired the critical mass to be called and taught as “phonetics” in many universities — if it is taught at all — is exclusively taxonomic phonetics.

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The line dividing between phonetic, phonological, and psychological studies of speech sounds is quite blurred in much current research, e.g., that of Pisoni [64], Fowler [23], Masaro [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 from the realm of the previously established — often that which has substantial empirical support. Its theories tend to contradict 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 and psychology and autonomous 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, the word ‘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 simply drop these extravagant claims. I make this proposal seriously: even astrology and astronomy could be reconciled if the empirically indefensible claims

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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 of investigation area becomes too large for individual practitioners to master. This happened with organic and inorganic chemistry, particle physics, etc. What shall we call it? 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.

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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, psycholinguistics, 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 underlie 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 Picioni [64], Faure [73], Massaro [47], Nearcy [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 concern 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.

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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-dependent 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 nonconcatenative unit underlying speech there is not much agreement on what it is. Various proposals exist concerning the phoneme, the phone (not the same as the phoneme but drawn from a much larger set since there is no posited functional identity between all the phones of the diphone, the diphthong, the disyllable, 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 those 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 identity [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 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-à-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 glibly accepted claims based on their superficial plausibility, mere internal consistency, or their fashionability. But rather than on the rigorously gathered evidence supporting them. In any case, it is premature to judge integrative phonology was right 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 rhyming tableaux, 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 phonometric 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 pipe-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 heading 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 phonetism, 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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