

# Phonetics Analytics in DROP

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**Phonetics – Introduction**

**Overview**

1. Definition of Phonetics and Phoneticians: *Phonetics* is a branch of linguistics that studies how humans perceive and product sounds, or in the case of sign languages, the equivalent aspects of sign (O’Grady (2005), Wikipedia (2021)). Phoneticians – linguists who specialize in phonetics – study the physical properties of speech.
2. Disciplines that Comprise Phonetics Study: The field of phonetics is traditionally divided into three sub-disciplines based on the research questions involved such as how humans plan and execute movements to produce speech – articulatory phonetics; how different movements affect the properties of the resulting sound – acoustic phonetics; or how humans convert sound waves to linguistic movements – auditory phonetics.
3. Minimal Linguistic vs Phonological Unit: Traditionally, the minimal linguistic unit of phonetics has been the phone – a speech sound in a language – which differs from the minimal phonological unit of phoneme; the phoneme is an abstract categorization of phones.
4. Speech Perception/Production in Languages: Phonetics broadly deals with two aspects of human speech; a) the way humans make sounds, and b) perception – the way speech is understood. The communication modality of a language describes the method by which a language produces and perceives speech.
5. Languages with Oral-Aural Modalities: Languages with oral-aural modalities such as English produce speech orally; i.e., using the mouth, and perceive speech aurally – using the ears.
6. Languages with Manual Visual Modalities: Sign languages, such Auslan and ASL, have a manual-visual modality, producing speech manually – using the hands – and perceiving speech visually – using the eyes.
7. Languages with Tactile Signing Modality: ASL and some other sign languages in addition have a manual-manual dialect for use in tactile signing in deafblind speakers where the signs are produced by the hands and perceived by the hands as well.
8. Non-linguistic to Speech Translation: Language production consists of several independent processes which transform a non-linguistic message into a spoken or signed linguistic signal.
9. Lexical Selection - Choosing Word Items: After identifying a message to be linguistically encoded, a speaker must select the individual words – known as lexical items – to represent that message in a process called lexical selection.
10. Assignment of Words to Phonemes: During phonological encoding, the mental representation of the words is assigned their phonological content as a sequence of phonemes to be produced. These phonemes are specified for articulatory features which denote particular goals such as closed lips or the tongue in a particular position.
11. Phonemes as Muscle Command Sequence: These phonemes are then coordinated into a sequence of muscle commands that can be sent to muscles, and when these commands are executed properly the intended sounds are produced.
12. Airstream Disruption/Modification using Articulators: These movements disrupt and modify an airstream which results in a sound wave. The modification is done by articulators, with different places and manners of articulation producing different results.
13. Places and Manner of Articulation: For example, the words *task* and *sack* both begin with alveolar sounds in English, but differ in how far the tongue is from the alveolar ridge. The difference has large effects on the airstream and thus the sound that is produced. Similarly, the direction and the source of the airstream can affect the sound.
14. Pulmonic/Glottal/Lingual Airstream Modification: The most common airstream mechanism is pulmonic – using the lungs – but the glottis and the lungs can also be used to produce airstreams.
15. Decoding Signals into Linguistic Units: Language perception is the process by which a linguistic signal is decoded and understood by the listener. In order to perceive speech, the continuous acoustic signal must be converted into discrete linguistic units such as phonemes, morphemes, and words.
16. Detection of the Linguistic Categories: In order to correctly identify and categorize sounds, listeners prioritize certain aspects of the signal that can reliably distinguish between linguistic categories.
17. Visual Information Augmenting Acoustic Cues: While certain cues are prioritized over others, many aspects of the signal can contribute to perception. For example, though oral languages prioritize acoustic information, the McGurk effect shows that the visual information is used to distinguish ambiguous information when acoustic ones are unreliable.
18. Articulatory Phonetics: Modern phonetics has three main branches. The first, articulatory phonetics, studies the way sounds are made with the articulators.
19. Acoustic Phonetics: This studies the acoustic results of different articulations.
20. Auditory Phonetics: This studies the way listeners perceive and understand linguistic signals.

**Phonetics**

1. Sequential Steps of Speech Production: Language production consists of several inter-dependent processes which transform a non-linguistic message into a spoken or signed linguistic signal. Linguists debate whether the process of language production occurs in a series of stages, i.e., serial processing, or whether production processes occur in parallel.
2. Linguistic Encoding through Lexical Selection: After identifying the message to be linguistically encoded, a speaker must select the individual words – known as lexical items – to represent that message in a process called lexical selection.
3. Word’s Lemma - Semantic/Grammatic Determination: The words are selected based on their meaning, which in linguistics is called semantic information. Lexical selection activates the word’s lemma, which contains both semantic and grammatic information about the word (Dell and O’Seaghdha (1992)). Again, linguists debate whether these stages can interactor whether they occur serially – for e.g., compare Motley, Camden, and Baars (1982) with Dell and O’Seaghdha (1992). For ease of description, the language production process is this chapter is described as a series of independent stages, though recent evidence shows that this is inaccurate (Sedivy (2019)). Jaeger, Furth, and Hilliard (2012) contain further description of the interactive activation models.
4. Transferring Lexical Words to Phonemes: After an utterance has been planned – or after part of an utterance has been planned (Gleitman, January, Nappa, Trueswell (2007) provide evidence for production before a message has been completely planned), it then goes through phonological encoding. In this stage of language production, the mental representation of the words are assigned their phonological content as a sequence of phonemes.

**References**

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**Phonology - Introduction**

**Overview**

1. Alternate Meanings of the Term Phonology: *Phonology* is a branch of linguistics that studies how languages or dialects systematically organize their sounds – or signs, in sign languages. The term also refers to the sound system of any particular language variety.
2. Focus of the Phonology Field: At one time, the study of phonology only related to the study of systems of phonemes in spoken languages. Now it may relate to:
   1. Any linguistic analysis either at a level beneath the word – including syllables, onset and rime, articulatory gestures, articulatory features, mora, etc. OR
   2. All levels of language where sounds or signs are structured to convey linguistic meaning (Brentari, Fenlon, and Cormier (2018)).
3. Phonological Equivalents in Sign Languages: Sign languages have a phonological system equivalent to the system of sounds in spoken languages. The building blocks of signs are specifications for movement, location, and hand shape (Stokoe (1978)).

**Terminology**

1. Phonology as a Language System Component: The word *phonology* – as in *the phonology of English* – can also refer to the phonological system – the sound system – of a given language. This is one of the fundamental systems that a language is considered to comprise, like its syntax, its morphology, and its vocabulary.
2. Distinction between Phonology and Phonetics: Phonology is often distinguished from *phonetics*. While phonetics concerns the physical production, acoustic transmission, and perception of the sounds of speech (Lass (1998), Carr (2003)), phonology describes the way sounds function within a given language or across languages to encode meaning.
3. Distinction between Theoretical/Descriptive Linguistics: For many linguists, phonetics belongs to descriptive linguistics, and phonology to theoretical linguistics, although establishing a phonological system of a language is necessarily an application of theoretical principles to the application of phonetic evidence.
4. Conflation between Phonology and Phonetics: This distinction was not always made, particularly before the development of the modern concept of the phoneme in the mid-20th century.
5. Crossover of Phonology with Phonetics: Some sub-fields of modern phonology have a cross-over with phonetics in descriptive disciplines such as psycholinguistics and speech perception, resulting in specific areas such as articulatory phonology or laboratory phonology.

**Derivation and Definitions**

1. Origin of the Term Phonology: The word *phonology* comes from the ancient Greek φωυη, *phone, voice, sound*, and the suffix -*logy*, which is from the Greek λογος, *logos, word, speech, subject of discussion*.
2. Trubetzkoy’s Definition of the Term: Trubetzkoy (1939) defines phonology as *the study of sound pertaining to the system of language*, as opposed to phonetics, which is *the study of sound pertaining to the act of speech* – the distinction between *language* and *speech* being basically Saussure’s distinction between *langue* and *parole*.
3. Lass Definition of the Term: Lass (1998) writes the phonology broadly refers to the sub-discipline of linguistics concerned with the sounds of language, while in more narrow terms, *phonology proper is concerned with the function, behavior, and organization of sounds as linguistic items*.
4. Definition of Clark, Yallop, and Fletcher: According to Clark, Yallop, and Fletcher (2007), it means the systematic use of sound to encode meaning in any spoken human language, or the field of linguistics studying this use.

**Analysis of Phonemes**

1. Decomposed Units of Distinctive Sounds: An important part of traditional, pre-generative schools of philosophy is studying which sounds can be grouped into distinctive units within a language; these units are known as phonemes.
2. Example: Phoneme Units in English: For example, in English the *p* sound in *pot* is aspirated, while that in *spot* is not aspirated. However, English speakers treat both sounds as variations/allophones – of the same phonological category, that is of the phoneme *p*. Traditionally, it would be argued that if an aspirated *p* were interchanged with an unaspirated *p* in *spot*, native English speakers will still hear the same words; that is, the two sounds are perceived as *the same* p.
3. Phoneme Units in other Languages: In some other languages, however, these two sounds are perceived as different, as they are consequently assigned to different phonemes. For example, in Thai, Hindi, and Quechua, there are minimal pairs of words for which the aspiration is the only contrasting feature – two words can have different meanings but with the only difference in pronunciation being that one has an aspirated sound where the other has an unaspirated one.
4. Sound Inventory of Native Speakers: Part of the phonological study of language therefore involves looking at data – phonetic transcriptions of the speech of native speakers – and trying to decide what the underlying phonemes are and what the sound inventory of the language is.
5. Criteria for Identifying Minimal Pairs: The presence or absence of minimal pairs, as mentioned above, is a frequently used criteria for deciding whether two sounds should be assigned to the same phoneme. However, other considerations often need to be taken into account as well.
6. Historical Evolution of Language Phonemes: The particular contrasts which are phonemic in a language can change over time. At one time, [f] and [v], two sounds that have the same place and the manner of articulation and differ in voicing only, were allophones of the same phoneme in English, but later come to belong to separate phonemes. This is one of the main factors of historical change of languages as described in historical linguistics.
7. Interchanging the Allophones of Phonemes: The findings and insights of speech perception and articulation research complicate the traditional and somewhat intuitive idea of interchangeable allophones being perceived as the same phoneme.
8. Gibberish resulting from Allophone Switch: First, interchanged allophones of the same phoneme can result in unrecognizable words.
9. Highly Co-articulated Low-level Speech: Second, actual speech, even at a word level, is highly co-articulated, so it is problematic to be able to splice words into simple segments without affecting speech perception.
10. Assigning Sounds to Individual Phonemes: Different linguists therefore take different approaches to the problem of assigning sounds to phonemes.
11. Constraints around Allophone Sounds: For example, they differ in the extent to which they require the allophones to be phonetically similar.
12. Equivalence with the Brain Functions: There are also differing ideas as to whether this grouping of sounds is purely a tool for linguistic analysis, or reflects an actual process in the way human brain processes a language.
13. Idea behind Morphophonemes and Morphophonology: Since the early 1960s. theoretical linguistics have moved away from the traditional concept of a phoneme, preferring to consider the basic units at a more abstract level, as a component of morphemes; these units are called *morphophonemes*, and analysis using this approach is called morphophonology.

**Other Topics in Phonology**

1. Aspects of Phonological Studies - #1: In addition to the minimal units that can serve the purpose of differentiating meaning – the phonemes, phonology studies how sounds alternate, i.e., replace one another in different forms of the same morpheme – allomorphs, as well as, for example, syllable, stress, feature geometry, and intonation.
2. Aspects of Phonological Studies - #2: Phonology also includes such topics as phonotactics – the phonological constraints on what sounds can appear in what positions in a given language – and phonological alternation – how the pronunciation of a sound changes through the application of phonological rules, sometimes in a given order which can be feeding or bleeding (Goldsmith (1995)), as well as prosody, the study of supra-segmentals, and topics such as stress and intonation.
3. Phonology applied to Sign Languages: The principles of phonology can be applied independently of modality because they are designed to serve as general analytical tools, not language specific ones. The same principles have been applied to analysis of the sign languages, even though the sub-lexical units are not instantiated as speech sounds (Wikipedia (2020)).

**References**

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**Phoneme**

**Overview**

1. Definition of a Phoneme: A *phoneme* is a unit of sound that distinguishes one word from another in a particular language (Wikipedia (2020)).
2. Meaning - Contrast through Minimal Pair: For example, in most dialects of English, with the notable exception of West Midlands and the Northwest of England (Wells (1982)), the sound patterns for *sin* and *sing* are two separate words that are distinguished by the substitution of one phoneme */n/* for another phoneme */nj/*. Two like this that differ in meaning through the contrast of a single phoneme form a *minimal pair*.
3. Phonetic Variants of a single Phoneme: If, in another language, any two sequences differ only by the pronunciation of their final sounds *[n]* and *[nj]* are perceived as being the same in the meaning, then these two sounds are interpreted as phonetic variants of a single phoneme in that language.
4. Notation for Representing a Phoneme: Phonemes that are established by the use of minimal pairs, such as *tap* vs *tab* or *pat* vs *bat*, are written between slashes: */p/*, */b/*. To show pronunciation, linguists use square brackets: *[ph]* - indicating an aspirated *p* in *pat*.
5. Analyzing a Language through its Phonemenes: There are two different views as to exactly what phonemes are and how a given language should be analyzed in *phonemic* - or *phonematic* - terms.
6. Conceptual Idea behind a Phoneme: However, a phoneme is generally regarded as an abstraction of a set - or equivalence class - of speech sounds - *phones* - that are perceived as equivalent to each other in a given language. For example, the English *k* sounds in the words *kill* and *skill* are not identical - as described below - but they are distributional variants of a single phoneme */k/*.
7. Allophonic Variants of a Phoneme: Speech sounds that differ but do not create a meaningful change in the word are known as *allophones* of the same phoneme.
8. Factors Contributing to Allophonic Realization: Allophonic variation may be conditioned, in which case a certain phoneme is realized as a certain allophone in particular phonological environments, or it may otherwise be free, and may vary by speaker of dialect.
9. Language Phonemes versus Speech Sounds: Therefore, phonemes are often considered to constitute an abstract underlying representation for segments of words, while speech sounds makeup the corresponding phonetic realization, or the surface form.

**Notation**

1. Phonemes vs. Speech Sound Representation: Phonemes are conventionally placed between slashes in transcription, whereas speech sounds - phones - are placed in square brackets. Thus, */p omega integral/* represents a sequence of three phonemes, */p/*, */omega/*, */integral/* - the word *push* in Standard English, and *[ph omega integral]* represents the phonetic sequence of sounds *[ph]* - aspirated *p* - *[v]*, *[integral]* - the usual pronunciation of *push*.
2. Orthography Representation using Grapheme Units: This should not be confused with the similar convention of the use of angle brackets to enclose the units of orthography, graphemes. For example, *<f>* represents the written letter - grapheme - *f*.
3. IPA Based Phoneme Symbol Set: The symbols for particular phonemes are often taken from the International Phonemic Alphabet (IPA), the same set of symbols most commonly used for phones. For computer-typing purposes, systems such as X-SAMPA exist to represent IPA symbols using only ASCII characters.
4. Custom Transcription of Language Phonemes: However, descriptions of particular languages may use different conventional symbols to represent the phonemes of those languages. For languages whose writing systems employ the phonemic principle, ordinary letters my be used to denote phonemes, although this approach is often hampered by the complicated relationship between orthography and pronunciation.

**Assignment of Speech Sounds to Phonemes**

1. Uniqueness of Meaning/Speech Unit: A phoneme is a sound or a group of different sounds perceived to have the same function by the speakers of the language or dialect in question.
2. Example of Phoneme in English: An example is the English phoneme */k/*, which occurs in words such as *c*at, *k*it, s*c*at, and s*k*it. Although most native speakers do not notice this, in most English dialects, the *c/k* dialects are not identical; in *kit* *[khit]* the sound is aspirated, but in *skill* *[skil]*, it is unaspirated.
3. Similarity of the Speech Sounds: The words, therefore, contain different *speech sounds*, or *phones*, transcribed *[kh]* for the aspirated form and *[k]* for the unaspirated one.
4. Variations of the Phonemic Unit: These sounds are nonetheless considered to belong to the same phoneme, because if the speaker used one instead of the other, the meaning of the word would not change; using the aspirated form *[kh]* in *skill* might sound odd, but the word would still be recognized.
5. Phone Change Induced by Meaning Difference: By contrast, some other sounds would cause a change in meaning if substituted; for example, substitution of the sound *[t]* would produce a different word s*t*ill, and that sound must therefore be considered to represent a different phoneme - the phoneme */t/*.
6. Scheme for Identification of Phonemes: The following simplified procedure is used for determining whether two sounds represent the same or different phonemes.
7. Determining Phonemic Status of Sounds:
8. English Allophones *[k]* and *[kh]*: The above shows that in English *[k]* and *[kh]* are allophones of a single phoneme */k/*.
9. *[k]* and *[kh]* as Non-phonemic: In some languages, however, *[k]* and *[kh]* are perceived as different sounds, and substituting one for another can change the meaning of the word. In those languages, therefore, the sounds represent different phonemes.
10. Icelandic Language *[k]* and *[kh]*: For example, in Icelandic, *[kh]* is the first sound of *ka'tur*, meaning cheerful, but *[k]* is the first sound of *ga'tur*, meaning *riddler*. Icelandic, therefore, has two separate phonemes */kh/* and */k/*.

**Minimal Pair**

1. Existence of the Minimal Pair: A pair of words like *ka'tur* and *ga'tur* above that differ only in one phone is called the minimal pair for the two alternative phones in question - in this case *[k]* and *[kh]*.
2. Minimal Pair Check for Phonemes: The existence of minimal pairs is a common test to decide whether two phones represent different phonemes or are allophones of the same phoneme.
3. Minimal Pair Presence - English Example: To take another example, the minimal pair *t*ip and *d*ip illustrate that in English, *[t]* and *[d]* belong to separate phonemes */t/* and */d/*; since both words have different meanings. English speakers must be conscious of the distinction between the two sounds.
4. Minimal Pair Absence - Korean Example: In other languages, however, including Korean, both sounds *[t]* and *[d]* occur, but no such minimal pair exists.
5. *[t]* and *[d]* as Allophones: The lack of minimal pairs distinguishing *[t]* and *[d]* in Korean provides evidence that they are allophones of a single phoneme */t/*. The word */tada/* is pronounced *[tada]*, for example.
6. Perception Variation across different Languages: That is, when they hear this word, Korean speakers perceive the same sound in both the beginning and the end of the word, but English speakers perceive different sounds in these two locations.
7. Minimal Pairs in ASL Expressions: Sign languages, such as American Sign Languages ASL also have minimal Pairs, different only in exactly one of the sign parameters: handshape, movement, location, palm orientation, and non-manual signal or marker.
8. Parameters Guiding ASL Minimal Pair: A minimal pair may exist in the sign language if the basic sign remains the same, but one of the parameters changes.
9. Phonetic Marker Dissimilarity for Phonemes: However, the absence of minimal pairs for a given pair of phones does not always mean that they belong to the sane phoneme: they may be so dissimilar phonetically that it is unlikely for speakers to perceive them as the same sound.
10. Phonetic Marker Example in English: For example, English has no minimal pair for the sounds *[h]* - as in *h*at - and *[n,]* - as in ba*ng*, and the fact that they can be shown to be in complementary distribution could be argued for their being allophones of the same phoneme. However, they are so dissimilar phonetically that they are considered separate phonemes (Wells (1982)).
11. Case of "Near Minimal Pairs": Phonologists have sometimes had to recourse to "near minimal pairs" to show that speakers of the language perceive the two sounds as significantly different even if no minimal pair exists in the lexicon.
12. Near Minimal Pair English Example: It is virtually impossible to find a minimal pair to distinguish */integral/* from */z/*, yet it seems uncontroversial to claim that the two consonants are distinct phonemes. The two words *pleasure* and *pressure* can serve as a minimal pair (Wells (1982)).

**Suprasegmental Phonemes**

1. Suprasegmental Phonemes Impact Word Meanings: Besides segmental phonemes such as vowels and consonants, there re also suprasegmental features of pronunciation - such as tone and stress, syllable boundaries, and other forms of juncture, nasalization, and vowel harmony - which, in many languages, can change the meaning of the words and so are phonemic.
2. Phonemic Stress Impacting Word Meanings: *Phonemic stress* is encountered in languages such as English. For example, the word *invite* stressed on the second syllable is a verb, but when stressed on the first syllable - without changing any of the individual sounds - it becomes a noun.
3. Phonemic Specification of the Word: The position of the stress in the word affects the meaning, so a full phonemic specification - providing enough detail to enable the word to be pronounced unambiguously - would include indication of the position of the stress: */inv'ait/* for the verb, */'invait/* for the noun.
4. Languages where Stress is Non-phonemic: In other languages, such as French, word stress cannot have this function - its position is generally predictable - and is therefore not phonemic, and is not usually indicated in dictionaries.
5. Phonemic Tones Impacting Word Meanings: *Phonemic tones* are found in languages such as Mandarin Chinese, in which a given syllable can have 5 different tonal pronunciations.
6. Phonetic Variants of the Word *Ma*:
7. Meanings Induced by Tonal Variations: Here, the character pronounced *m~~a~~* - high level pitch - means *mother*; *ma'*, rising pitch, means *hemp*; *mau*, falling then rising, means *horse*; *ma`*, falling, means *scold*; and *ma*, neutral tone, is an interrogative particle. The tone phonemes in such languages are called *tonemes*.
8. Phonemic Intonation Impacting Word Meanings: Languages such as English do not have phonemic tones, although they use intonation for functions such as emphasis and attitude.

**Distribution of Allophones**

1. Complementary Distribution of Allophones: When a phoneme has more than one allophone, the only actually heard at the given occurrence of that phoneme may be dependent on the phonetic environment, i.e., surrounding sounds; allophones which normally cannot appear in the same environment are said to be in the complementary distribution.
2. Free Variation in the Allophones: In other cases, the choice of the allophone may be dependent on the individual speaker or other unpredictable factors - such allophones are said to be in free variation, but allophones are still selected in a specific phonetic context, not the other way around.

**Background and Related Ideas**

1. Meaning of the Greek Word: The term *phoneme* - from the ancient Greek *pho-ne-ma* - "sound made, utterance, thing spoken, speech, language" (Liddell and Scott (1940)) - was reportedly used first by Dufriche-Desgenettes in 1873, but it referred only to a speech sound.
2. Fonema - Basic Unit of Psychophonetics: The term *phoneme* as an abstraction was developed by the Polish linguist Jan Niecislaw Baudouin de Courtenay and his student Nikolaj Kruszewski during 1875-1895 (Jones (1957)). The term used by these two was *fonema*, the basic unit of what they called *psychophonetics*.
3. Modern Usage of the Word Phoneme: Jones (1919) became the first linguist in the Western world to use the word *phoneme* in the current sense.
4. Elaboration of the Phoneme Concept: The concept of the phoneme was then elaborated in the works of Nikolai Trubetzkoy and others of the Prague during the years 1926-1935, and in those of the structuralists like Ferdinand de Saussure, Edward Sapir, and Leonard Bloomfield.
5. Psycholinguistic Role for Phonemes: Some structuralists - though not Sapir - rejected the idea of a cognitive or psycholinguistic function for the phoneme (Twaddell (1935), Harris (1951)).
6. Deprecation/Enhancement of the Phoneme Concept: Later, it was used and redefined in generative linguistics, most famously by Chomsky and Halle (1968), and remains central to many accounts of the development of modern phonology. As a theoretical concept or model, however, it has been supplemented and even replaced by others (Clark and Yallop (1995)).
7. Decomposition of Phonemes into Features: Some linguists - such as Jakobson and Halle (1968) - proposed may be further decomposed into features, such features being the minimal constituents of language.
8. Evolution of Sub-phonemic Features: Features overlap each other in time, as do suprasegmental phonemes in oral languages and many phonemes in sign languages.
9. Schemes for Extracting the Features: Features can be characterized in different ways: Jakobson, Fant, and Halle (1952) described them in acoustic terms, Chomsky and Halle used a predominantly articulatory basis, though retaining some acoustic features, while Ladefoged's system (Ladefoged (2006)) is purely an articulatory system apart from the use of the acoustic term 'sibilant'.
10. Duration Chronemes and Tone Phonemes: In the description of some languages, the term *chroneme* has been used to indicate the contrastive length or *duration* of phonemes. In languages in which tonemes are phonemic, the tone phonemes may be called tonemes.
11. Widespread Acceptance of the Above Terms: Though not all scholars working on such languages use these terms, they are by no means obsolete.
12. Other Fundamental Units in Linguistics: By analogy with the phoneme, linguists have proposed other sorts of underlying objects, giving them names with the suffix *-eme*, such as *morpheme* and *grapheme*. These are sometimes called emic units.
13. Generalization of Emics and Etics: The latter term was first used by Pike (1967), who generalized the concepts of emic and etic descriptions - from *phonemic* and *phonetic* respectively - to applications outside linguistics.

**Restrictions on Occurrence**

1. Phonotactic Combinations Constraints - Restricted Phonemes: Languages do not allow generally words or syllables to be built of any arbitrary sequence of phonemes; there are phonotactic restrictions on which sequences are possible and in which environments certain phonemes can occur. Phonemes that are significantly limited by such restrictions may be called *restricted phonemes*.
2. Phonemic Restrictions in English #1: In English, examples of such restrictions include: /n\_j/, as in *si****ng***, occurs only at the end of a syllable, never at the beginning - in many other languages, such as Maori, Swahili, Tagalog, and Thai, /n\_j/ can appear word-initially.
3. Phonemic Restrictions in English #2: /h/ occurs only before vowels and at the beginning of a syllable, never at the end - a few languages, such as Arabic or Romanian, allow /h/ syllable-finally.
4. Phonemic Restrictions in English #3: In non-rhotic dialects, /inverse\_r/ can only occur before a vowel, never before a consonant.
5. Phonemic Restrictions in English #4: /w/ or /j/ occur only before a vowel, never at the end of a syllable - except in interpretations where a word like *boy* is analyzed as /b mirrored\_c j/.
6. Analysis using Neutralization and Archiphonemes: Some phonotactic restrictions can alternatively be analyzed as cases of neutralization. In the below section on Neutralization and archiphonemes, a particular example of the occurrence of the three English nasals before stops is shown.

**Biuniqueness**

1. Meaning of the Biuniqueness Requirement: Biuniqueness is a requirement of the classical structuralist phonemics. It means that a given phone, wherever it occurs, must be unambiguously assigned to one and only one phoneme. In other words, the mapping between phones and phonemes is required to be many-ti-one rather than many-to-many.
2. Controversial Nature of the Postulate: The notion of biuniqueness was controversial among some pre-generative linguists and was prominently challenged by Halle and Chomsky in the late 1950s and early 1960s.
3. Alveolar Flaps as a Counter-point: An example of the problems arising frm the biuniqueness requirement is provided by the phenomenon of flapping in North American English. This may cause either /t/ or /d/ - in the appropriate environments - to be realized with the phone [snipped r] - an alveolar flap.
4. Non-contrastive Phonemes - Contextual Realization: For example, the same flap sound may be heard in the words *hi****tt****ing* and *bi****dd****ing*, although it is intended to realize the phoneme /t/ in the first word and /d/ in the second. This appears to contradict biuniqueness. The next section has a detailed discussion of such cases.

**Neutralization an Archiphonemes**

1. Neutralization of the Phonemic Contrast: Phonemes that are contrastive in certain environments may not be contrastive in all environments. In environments where they do not contrast, the contrast is said to be *neutralized*. In these positions, it may become less which phoneme a given phone represents.
2. Non-realized Phonemes - Absolute Neutralization: *Absolute Neutralization* is a phenomenon in which a segment of the underlying realization is not realized in any of phonetic representations.
3. Non-contrastive Phonemes - Contextual Realization: The term was introduced by Kiparsky (1968), and contrasts with *contextual neutralization* where some phonemes are not contrastive in certain environments.
4. Representation using Under-specification - Archiphoneme: Some phonologists prefer not to specify a unique phoneme in such cases, since to do so would mean providing redundant or even arbitrary information - instead they use the technique of under-specification. An *archiphoneme* is an object sometimes used to represent an under-specified phoneme.
5. Example: Stressed/Unstressed Contrastive Realizations: An example of neutralization is provided by the Russian vowels /a/ and /o/. These phonemes are contrasting in stressed syllables, but in unstressed syllables the contrast is lost, since both are reduced to the same sound - usually [flipped\_e] - owing to vowel reduction in Russian.
6. Factors Impacting the Phonemic Assignment: In order to assign such an instance of [flipped\_e] to one of the phonemes /a/ and /o/, it is necessary to consider morphological factors, such as the vowels that occur in other forms of the words, or which inflectional pattern is followed. In some cases, this may not even provide an unambiguous answer.
7. Using Under-specification for Description: A description using the approach of under-specification would not attempt to assign [flipped\_e] to a specific phoneme in some or all of the cases, although it may be assigned to an archiphoneme, written something like //A//, which reflects two neutralized phonemes in this position.
8. English Example - Contrasting Nasal Phonemes: A somewhat different example is found in English, with the three nasal phonemes /m, n, n\_j/. In word-final position, all these contrast, as shown by the minimal triplet *sum* /s^m/, *sun* /s^n/, *sung* /s^n\_j/.
9. Exclusiveness of Nasals Preceding Stops: However, before a stop such as /p, t, k/ - provided there is no morpheme boundary between them - only one of the nasals is possible in any given position: /m/ before /p/, /n/ before /t/ or /d/, and /n\_j/ before /k/, as in *limp*, *link*, *link*, - /limp/, /lint/, /lin\_jk/.
10. Non-contrastive Nature of these Phonemes: The nasals are therefore not contrastive in these environments, and according to some theorists this makes it inappropriate to assign the nasal phones heard here to any of the phonemes - even though, in this case, the phonetic evidence is unambiguous.
11. Archiphonemic Representation of these Nasals: Instead, they may analyze these phones as belonging to a single archiphoneme, written something like //N//, and state the underlying representations of *limp*, *link*, *link* to be //liNp//, //liNt//, //liNk//.
12. Alternate Notation for Representing Archiphonemes: This latter type of analysis is often associated with Nikolai Trubetzkoy of the Prague School. Archiphonemes are often notated with a capital letter within double virgules or pipes, as with examples //A// and //N// given above. Other ways the second of these has been notated include |m-n-n\_j|, {m, n, n\_j}, and //n\*//.
13. English Example - Alveolar Flap Phonemes: Another example from English, but this time involving complete phonetic convergence as in the Russian example, is the flapping of /t/ and /d/ in some accents of American English - described above under Biuniqueness.
14. Phonemes Implied by Consistent Flapping: Here the word *betting* and *bedding* may ne pronounced ['b epsilon snipped\_r i n\_j]. Under the generative grammar theory of linguistics, if a speaker applies such flapping consistently, morphological evidence - the pronunciation of the related forms *bet* and *bed*, for example - would reveal which phoneme the flap represents, once it is known which morpheme is being used (Dinnsen (1985)).
15. Archiphoneme Approach to Flap Determination: However, other theorists would prefer not to make such a determination, and simply asign the flap in both cases to a single archiphoneme, written - for example - //D??.
16. English Example - Plosives Succeeding /s/: Further mergers in English are plosives after /s/, where /p, t, k/ conflate with /b, d, g/, as suggested by the alternative spellings *sketti* and *sghetti*. That is, there is no particular reason to transcribe *spin* as /'spin/ rather than as /'sbin/, other than its historical development, and it may be less ambiguously transcribed as //'sBin//.

**Morphemes**

1. Sub-division into Morphophonemes and Morphemes: A *morphophoneme* is a theoretical unit at a deeper level of abstraction than traditional phonemes, and it taken to be a unit from which morphemes are built up.
2. Dividing Allomorphs to Uncover Morphophonemes: A morphophoneme within a morpheme can be expressed in different ways in different allomorphs of that morpheme - according to morphophonological rules.
3. Morphophonemic Representation of English Plurals: For example, the English plural morpheme *-s* appearing in words such as *cats* and *dogs* can be considered to be a single morphophoneme, which might be transcribed - for example - //z// or |z|, and which is realized as phonemically |s| after most voiceless consonants - as in *cat****s*** - and as |z| in other cases - as in *dog****s***.

**Number of Phonemes in Different Languages**

1. Phones Produced by Natural Languages: All known languages use only a small subset of the many possible sounds that the human speech organs can produce, and, because of allophones, the number of distinct phonemes will generally be smaller than the number of identifiably different sounds.
2. Phonemic Inventory Range across Languages: Different languages vary considerably in the number of phonemes that have in their systems, although apparent variation might sometime result from the different approaches taken by the linguists doing the analysis. The total phonemic inventory in languages varies from as few as 11 in Rotokas and Piraha to as many as 141 in !Xu~ (Crystal (2010)).
3. Lowest Count of Vowel Phonemes: The number of phonemically distinct vowels can be as low as 2, as in Ubuyk and Arrernte.
4. Highest Count of Vowel Phonemes: At the other extreme, the Bantu language Ngwe has 14 vowel qualities, 12 of which may occur long or short, making 26 oral vowels, plus 6 nasalized vowels, long and short, making a total of 38 vowels; while !Xo'o~ achieves 31 pure vowels, not counting the additional variation by vowel length, by varying the phonation.
5. Lowest Count of Consonant Phonemes: As regards consonant phonemes, Puinavae and the Papuan language Tauade each have just 7, and Rotokas has only 6.
6. Highest Count of Consonant Phonemes: !Xo'o~, on the other hand, has somewhere around 77, and Ubykh 81.
7. Vowel Phoneme Range in English: The English language uses a rather large set of 13-21 vowel phonemes, including diphthongs, although its 22-26 consonants are close to average.
8. Phonemes due to Tones/Stress: Some languages, such as French, have no phonemic tone or stress; while Cantonese and several other Kim-Sui languages have 9 tones, and one of the Kui languages, Wobe', has been claimed to have 14 (Bearth and Link (1980)), though this is disputed (Singler (1984)).
9. Common Vowel/Consonant Phoneme Set: The most common vowel system consists of 5 vowels /i/, /e/, /a/, /o/, /u/. The most common consonants are /p/, /t/, /k/, /m/, /n/ (Moran, McCloy, and Wright (2014)).
10. Languages that lack Common Consonants: Relatively few languages lack any of these consonants, although it does happen: for example, Arabic lacks /p/, standard Hawaiian lacks /t/, Mohawk and Tlingit lack /p/ and /m/, Hupa lacks both /p/ and a simple /k/, colloquial Samoan lacks /t/ and /n/, while Rotokas and Quileate lack /m/ and /n/.

**The Non-Uniqueness of Phonemic Solutions**

1. Uniqueness of the Phonemic Construct: During the development of the phoneme theory in the mid-20th century phonologists were concerned not only with the procedures and the principles involved in producing a phonemic analysis of the sounds in a given language, but also with reality or uniqueness of the phonemic solution.
2. Pike's Statement on Phonemic Uniqueness: Some writers took the position expressed by Pike (1947): "There is only one accurate phonemic analysis of a given set of data", while others believed that different analysis, equally valid, could be made for the same data.
3. Chao's Statement on Phonemic Uniqueness: Chao (1934) stated: "Given the sounds of a language, there are usually more than one possible way of reducing them to a set of phonemes, and those different systems or solutions are not simply correct or incorrect, but may be regarded as only being good or bad for various purposes".
4. Analysis Using English Vocal System: Householder (1952) referred to this debate within linguistics as "God's truth vs. hocus-pocus". Different analysis of the English vowel system may be used to illustrate this.
5. Wikipedia on English Vowel Phonemes: The article on English phonology (Wikipedia (2021)) states that English has a particularly large number of vwel phonemes, and that there are 20 vowel phonemes in Received Pronunciation, 14-16 in General American, and 20-21 in Australian English; the previous section indicated that the English language uses a rather large set of 13-21 vowel phonemes.
6. Alternate Transcription of English Phonemes: Although these figures are often quoted as a scientific fact, they actually reflect only one of many possible analysis, and Wikipedia (2021) suggests an alternate analysis in which some diphthongs and long vowels may be interpreted as comprising a short vowel linked to either /j/ or /w/.
7. Vowel Phonemes for RP: The transcription system for British English (RP) devised by Lindsay in 2017 and used in the CUBE pronunciation dictionary also treats diphthongs as composed of a vowel plus /j/ or /w/.
8. Exposition of Trager and Smith: The fullest exposition of this approach is found in Trager and Smith (1951) where all long vowels and diphthongs - "complex nuclei" - are made up of a short vowel combined with either /j/, /w/, or /h/ - plus /r/ for rhotic accents, each thus comprising two phonemes. They write: "The conclusion is inescapable that complex nuclei consist each of two phonemes, one of the short vowels followed by one of the 3 glides".
9. Alternate Transcriptions for the Words: The transcription for the vowel normally transcribed /ai/ would be instead /aj/, /a v with horns/ would be /aw/, and /a:/ would be /ah/.
10. Significantly Reduced Count of Vowels: The consequence of this approach is that English could theoretically have only 7 vowel phonemes, which is symbolized /i/, /e/, /a/, /o/, /u/, /^/, and /flipped-e/, or even 6 if schwa were treated as an allophone of /^/ or of other short vowels, a figure that would put English much closer to the average number of vowel phonemes in other languages.
11. Competing Basis for Phonemic Analysis: In the same period there was disagreement about the correct basis for phonemic analysis.
12. Analysis Using only Sound Elements: The structuralist position was that the analysis should be made purely on the basis of the sound elements and their distribution, with no reference to extraneous factors such as grammar, morphology, or the intuitions of native speakers; this position is associated with Bloomfield (1933).
13. Analysis Using Phonetic Segment Distribution: Harris (1951) claimed that it is possible to discover phonemes of a language purely by examining the distribution of phonetic segments.
14. Twaddell's Statement on Mentalistic Approaches: Referring to the mentalistic definitions of a phoneme, Twaddell (1935) states: "Such a definition is invalid because a) we have no right to guess about the linguistic workings of an inaccessible 'mind', and b) we can secure no advantage from such guesses. The linguistic processes of the 'mind' are as such quite simply unobservable, and introspection about linguistic processes is notoriously a fire in the wooden stove".
15. Value Attributed to Native Speaker's Intuition: Using English [n\_j] as an example, Sapir (1925) argued that, despite the superficial appearance that this belongs to a group of nasal consonants, "no native English speaking person can be made to feel in his bones that it belongs to a single series with /m/ and /n/ ... It still feels like n,g".
16. Emergence of Mentalist over Structuralist: The theory of generative phonology which emerged in the 1960's explicitly rejected the Structuralist approach to phonology and favored the mentalistic or cognitive view of Sapir (Chomsky (1964), Chomsky and Halle (1968)).

**Correspondence Between Letters and Phonemes**

1. Equivalence of Phonemes to Graphemes: Phonemes are considered to be the basis for alphabetic writing systems. In such systems, the written symbols - graphemes - represent, in principle, the phonemes of the language being written.
2. Alphabet System for Classical Latin: This is most obviously the case when the alphabet was invented with a particular language in mind; for example, the Latin alphabet was designed for Classical Latin, and therefore the Latin of that period enjoyed a near one-to-one correspondence between phonemes and graphemes in most cases, though the devisers of the alphabet chose not to represent the phonemic effect of vowel length.
3. Established Orthography vs. Evolving Phonemes: However, because changes in spoken language are not often accompanied by changes in established orthography - as well as other reasons, including dialect differences, the effects of morphophonology on orthography, and the use of foreign spellings for some loanwords - the correspondence between spelling and pronunciation in a given language may be highly distorted; this is the case with English, for example.
4. Correspondence between Phonemes and their Symbols: The correspondence between symbols and phonemes in alphabetic writing systems is not necessarily a one-to-one correspondence.
5. Phonemes Constructed using Letter Combinations: A phoneme might be represented by a combination of 2 or more letters - digraph, trigraph, etc., like <sh> in English or <sch> in German, both representing phoneme /integral/.
6. Single Symbol Representing Multiple Phonemes: Also, a single symbol may represent two phonemes, as in English <x> representing |gz| or /ks/.
7. Complications arising from Pronunciation Rules: There may also exist spelling/pronunciation rules - such as those for the pronunciation of <c> in Italian - that further complicate the correspondence of letters to phonemes, although they need not affect the ability to predict the pronunciation from spelling and vice versa, provided the rules are known.

**In Sign Languages**

1. Sign Language Articulation Feature Bundles: Sign language phonemes are bundles of articulation features. Stokoe was the first scholar to describe the phonemic system of ASL.
2. Identifiers from Tab/Dez/Sig: He identifies the bundles *tab* - elements of location, from Latin *tabula*, *dez* - the handshape, from *designator*, *sig* - the motion, from *signation*. Some researchers also discern *ori* - orientation, facial expression, or mouthing.
3. Sign Phonemes and Minimal Pairs: Just as with spoken languages, when features are combined, they create phonemes. As in spoken languages, sign languages have minimal pairs which differ in only one phoneme.
4. Examples - Father/Mother ASL Signs: For instance, the ASL signs for *father* - <https://media.spreadthesign.com/video/mp4/13/455635.mp4> - and *mother* - <https://media.spreadthesign.com/vides/mp4/13/48601.mp4> - differ minimally with respect to location while handshape and movement are identical; location is thus contrastive.
5. Limitations of Stokoe's terminology/Notation: Stokoe's terminology and notation system are no longer used by researchers to describe the phonemes of sign language; Stokoe's research, while still considered seminal, has been found to not characterize American Sign Language of other sign languages sufficiently (Clayton and Lucas (2000)).
6. Enhancement to Sign Language Phonology: For instance, non-manual features are not included in Stokoe's classification. More sophisticated models of sign language phonology have since been proposed by Sandler (1989), Brentari (1998), and van der Kooij (2002).

**Chereme**

1. The Basic Unit of Sign: *Cherology* and *chereme* - from Ancient Greek *chi epsilon i rho* "hand" - are synonyms of phonology and phoneme previously used in sign languages. A *chereme*, as the basic unit of signed communication, is functionally and psychologically equivalent to the phonemes of oral languages, and has been replaced by that term in the academic literature.
2. Cherology - Study of Sign Cheremes: *Cherology*, and the study of *cheremes* in language, is thus equivalent to phonology. The terms, are, not in use anymore. Instead, the terms *phonology* and *phoneme* - or *distinctive feature* - are used to stress the linguistic similarities between signed and spoken languages (Bross (2015)).
3. Acceptance of the above Terminology: The terms were coined by Stokoe (1960) at Gallaudet University to describe sign languages as true and full languages. Once a controversial idea, the position is now universally accepted in linguistics. Stokoe's terminology, however, has been largely abandoned.

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