Language

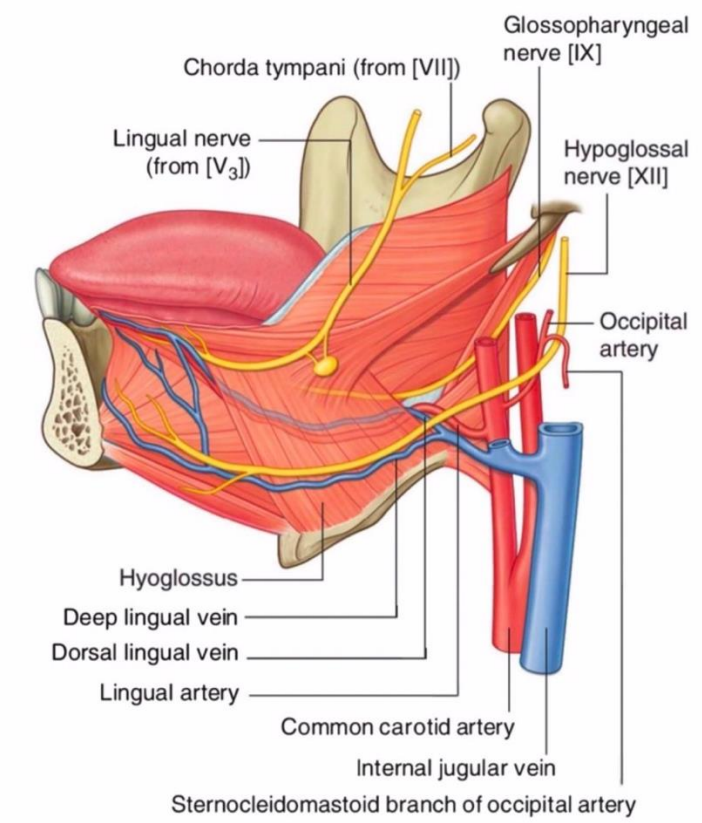
10/24/24

What is Language?

- **Language** is a structured system of communication, consisting of symbols, sounds, or gestures, used to convey meaning and facilitate interaction and understanding between individuals.
  - But it did not emerge out of nothing! Its evolutionary roots are found in more primitive forms of communication
- **Signaling theory**: evolutionary theory about how individuals communicate with each other, especially when there are conflicts of interest (costs, sexual selection, resource competition, predator-prey dynamics)
  - **Honest vs dishonest signals**: it is costly to produce a truthful signal making it reliably honest (e.g., a peacock's tail signaling good health), while a dishonest signal may exploit the system (mimicry of a more dangerous species to scare away, or of a vulnerable individual to act as a lure)

Origins of Language

- Early hominin communication relied on **body gestures**, facial expressions, and body movements, allowing direct conveyance of emotions, needs, intentions
  - Gestural signals are direct expressions of actions and emotions; they are transparent and hard to fake
- Growth of the **hypoglossal nerve** improved vocal control, allowing for **vocalizations** to be more complex
  - The **hypoglossal nerve** is a cranial nerve that innervates all the muscles of the tongue
- These primitive vocalizations became more symbolic, resembling a kind of "**musilanguage**"
  - **Intonation, phrasing,** and **rhythm** develop earlier and have more primitive neurobiological roots
  - Allows for direct emotional expression, improves social cohesion and coordination
  - Music came before than words!

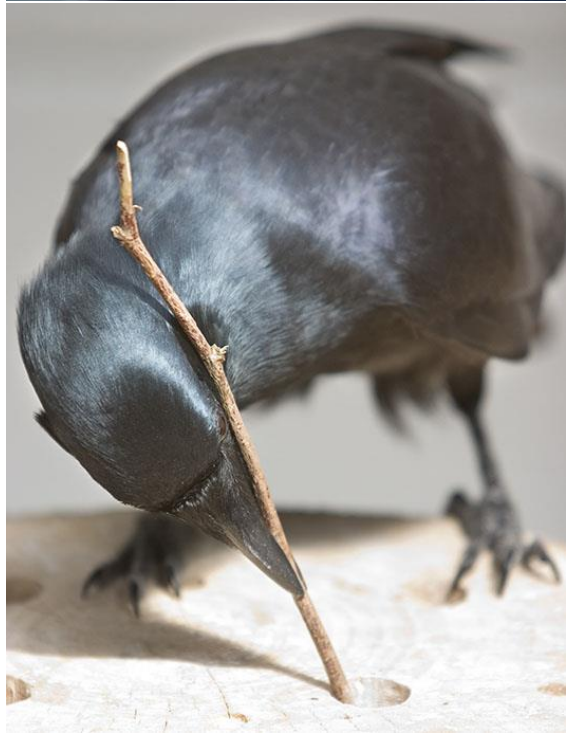


Proto-language

- Proto-language evolved through **poetic** and **musical** expressions, using rhythmic, repetitive patterns that conveyed **emotional** and **social** meaning
- These early communications developed **metaphorical** and **symbolic** representations, allowing for more abstract concepts
  - The ability to communicate about something that is not currently present to sensory experience
- **Modern abstract speech** emerged out of this, developing complex **syntactical structures** to have a precise and rule-based system that could communicate ideas
  - The ability to reference experiences that are not immediately present in a systematic way, with increasing abstraction

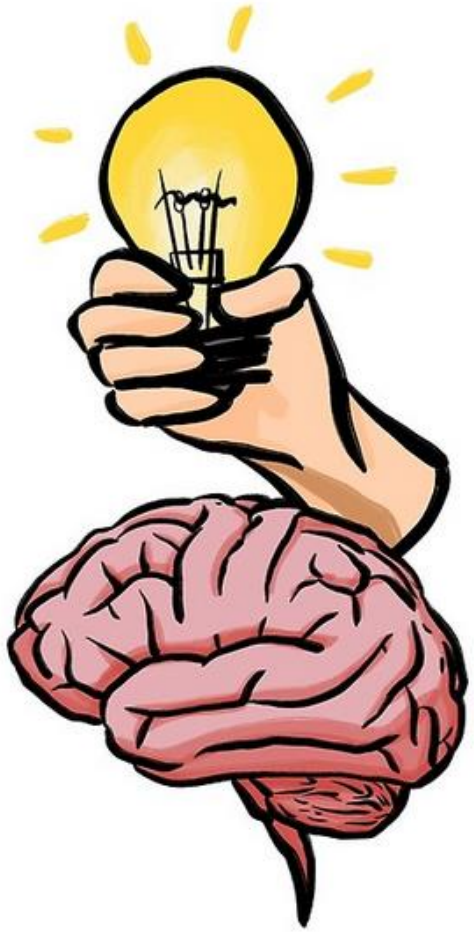
Thought and Language

- Thought comes before language; thinking is much more than some sort of internal linguistic monologue
- Forming categories, weighing and evaluating evidence, making decisions, solving problems, theory of mind (the ability to imagine others as having minds of their own), and even mathematical reasoning can occur without language ability
  - Evidence of these skills in animals, and/or in patients with brain damage
- The desire to communicate transcends language – rooted in goal-directed behavior and motivation, which is connected to the **anterior cingulate cortex (ACC)**
- So then what is language, really?



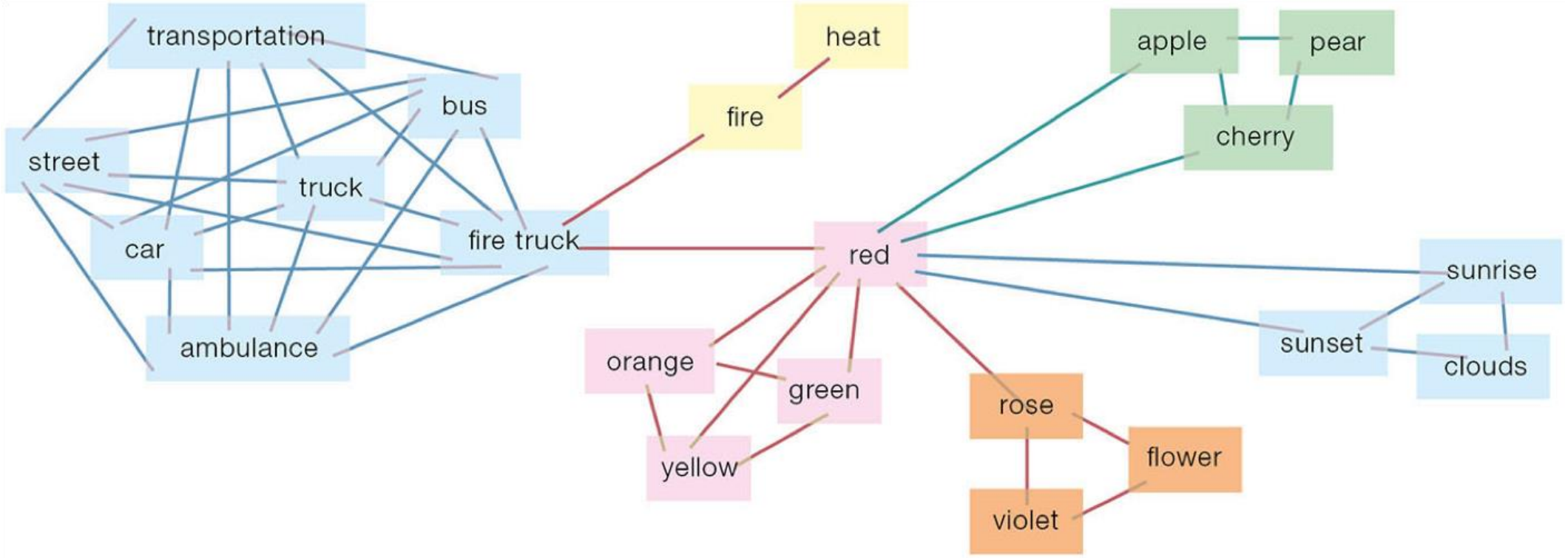
Language is a way to manipulate the world

- **Broca's area**, a key region for language, contains **mirror neurons** that are involved in hand and finger movement – **grasping**
- The metaphor of "grasping" an idea (or when you "can't put a finger on it") reflects how language ties physical actions to cognitive control and understanding
  - Grasp, com*prehend*, im*press*ion, ex*press*ion, in*tend*, con*tend*, pre*tend* (Latin *tendere*, to reach with the hand)
- **Naming** things (**referential language**) provides a stability and objectivity to the world, making it easier to understand, grasp, and manipulate
- Language creates a **virtual map** of reality – the ability to isolate concepts independent of their context



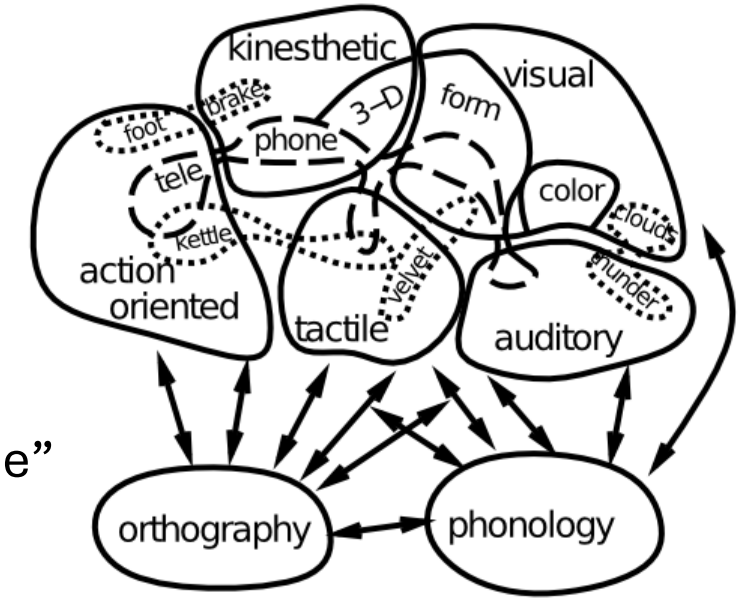
Meaning is distributed across a semantic network

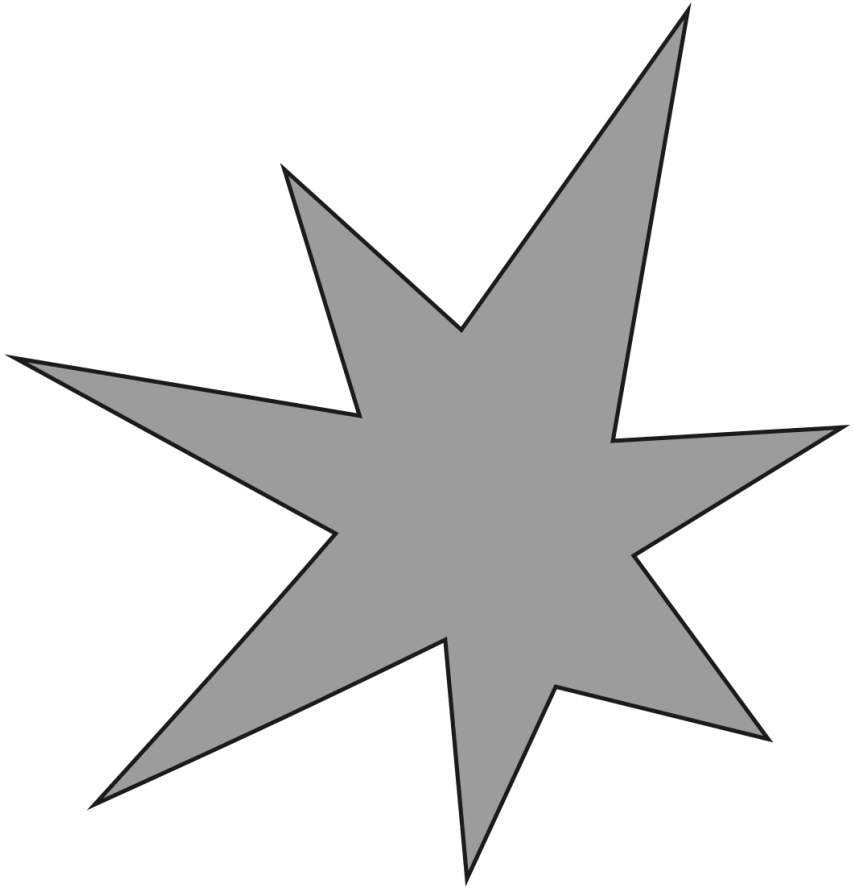
- The **mental lexicon** is a network of relationships between concepts

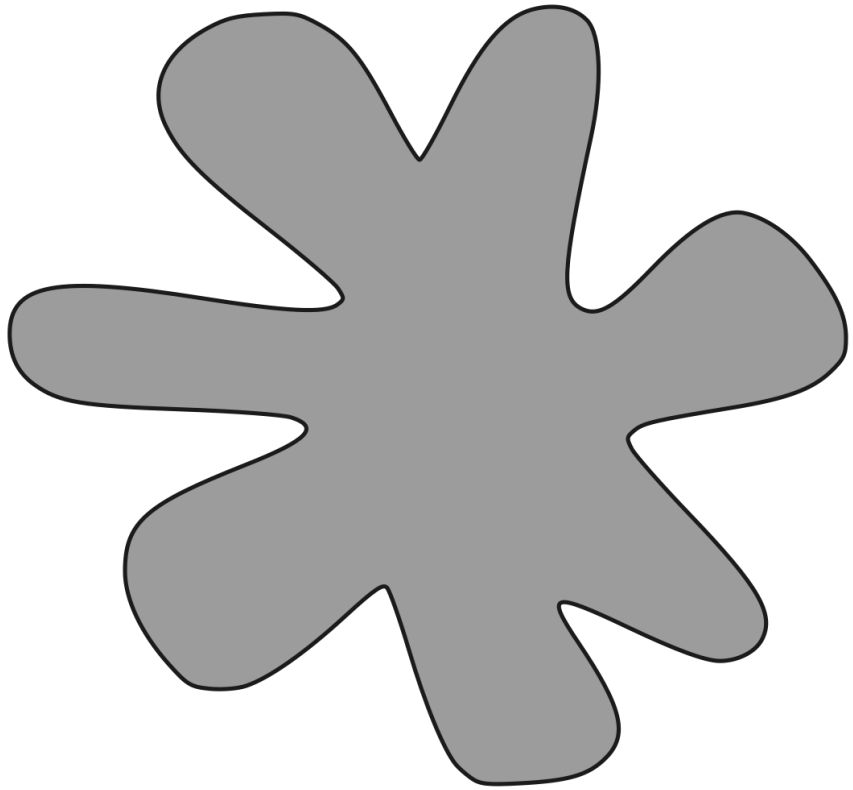


All language is metaphor

- **Metaphor** (Greek *meta-* across, *pherein* carry) is a cognitive tool for bridging a gap
  - All concepts must be somehow rooted in sensory experience, because this is the ultimate shared reference
  - Our language does not "ground" our experience, but it can "shape" it
- Examples:
  - Time as space – "looking forward to", a date is "ahead of us"
  - Understanding as seeing – "see what you mean", "bright idea"
  - Emotion as temperature – a "warm welcome," a "cold shoulder"
  - Love as taste – a "sweet gesture", a "bitter or sour attitude"
  - Danger as smell – something "smells fishy," can "sniff out a lie"
  - Visceral emotions – it "takes guts" to do that, "feel butterflies", "gut reaction"



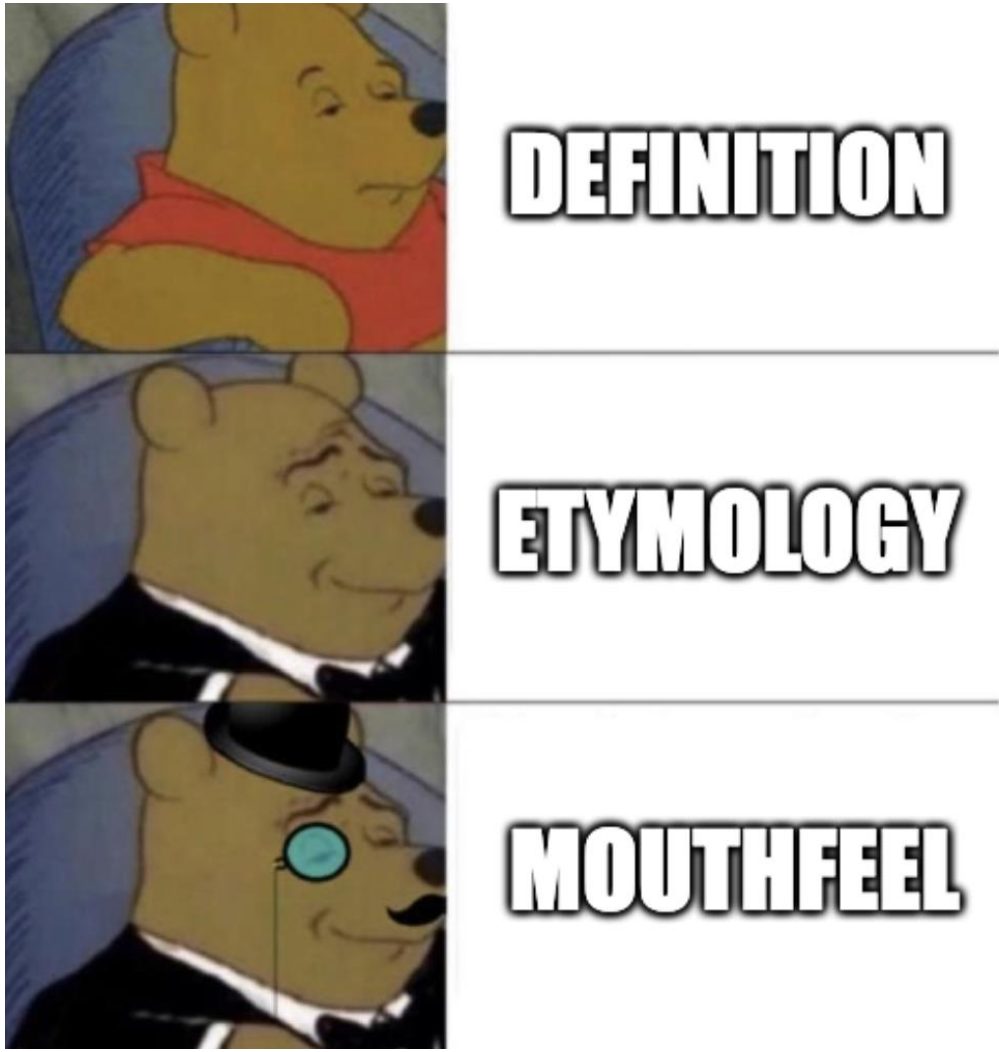




Which is bouba? Which is kiki?

Kiki/Bouba Effect

- Almost every culture knows the answer to this, and the ones that don’t are the exceptions that prove the rule (there is a specific explanation for why they don’t)
- **Sound symbolism**: there is a correspondence between speech sounds and visual and tactile experience, pointing to a universal intuitive aspect of language that is grounded in sensory experience
- Words are not arbitrary! The way they feel is quite literally a part of their meaning



Some sound symbolism examples

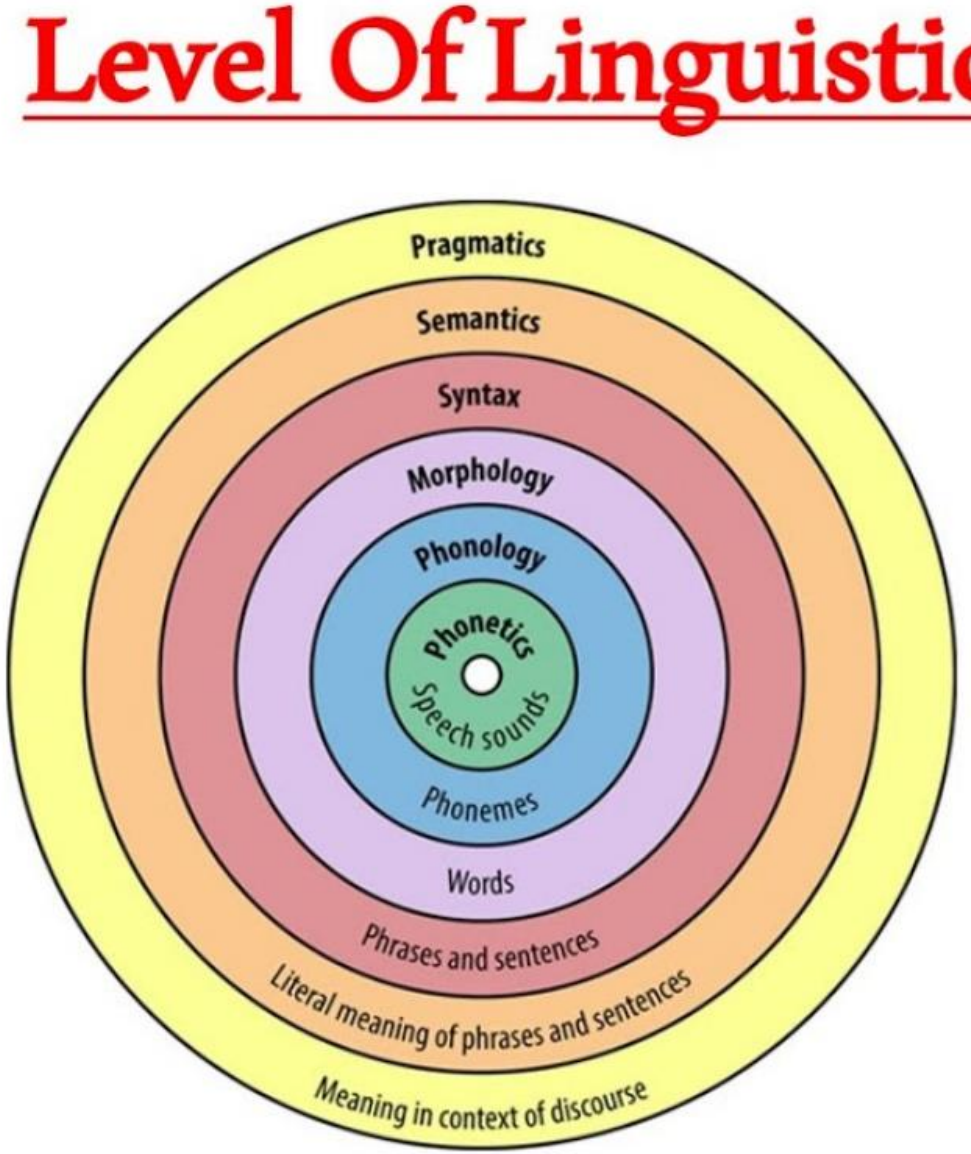
- The simplest form of sound symbolism in onomatopoeia, when a word sounds like the thing it refers to
- Some sounds like /b/ have a common energy to them… Barrier, bulge, bursting, banged, beaten, battered, bruised, blistered, bashed
- The /gl/ sound is bright and shiny… gloss, gleam, glow, glisten, glimmer, glitter, glare, glass, glitz
- The /fl/ sound is fast and light… fly, flee, flow, flimsy, flicker, fluid
- High, front vowel sounds like /ee/ and /i/ are small… teeny, tiny, petit, stick, bit, pin
- While low, back vowel sounds like /ah/ and /aw/ are bigger… large, broad, tall, log, haul

Systems involved in language

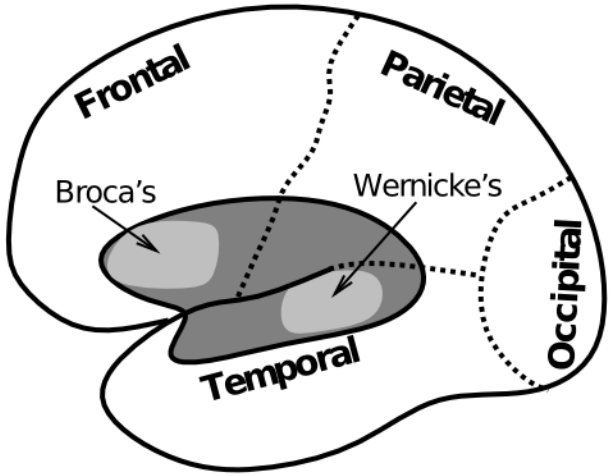
- **Perception** – perceiving sounds or text as words
  - Auditory and visual systems
- **Motor control** – speech is carefully refined motor output
  - Cerebellum and basal ganglia, and motor cortex
- **Learning and memory** – declarative memory to remember vocabulary, short-term memory to track sentences and grammar
  - Hippocampus, medial temporal lobe, frontal/prefrontal and parietal lobes
- **Executive functioning** – coordinating working memory and attention
  - Prefrontal cortex and basal ganglia
- **Culture** – language acquisition is one of the central pieces of cultural transmission, shaping the way a people communicate with each other and understand the world

Linguistic concepts

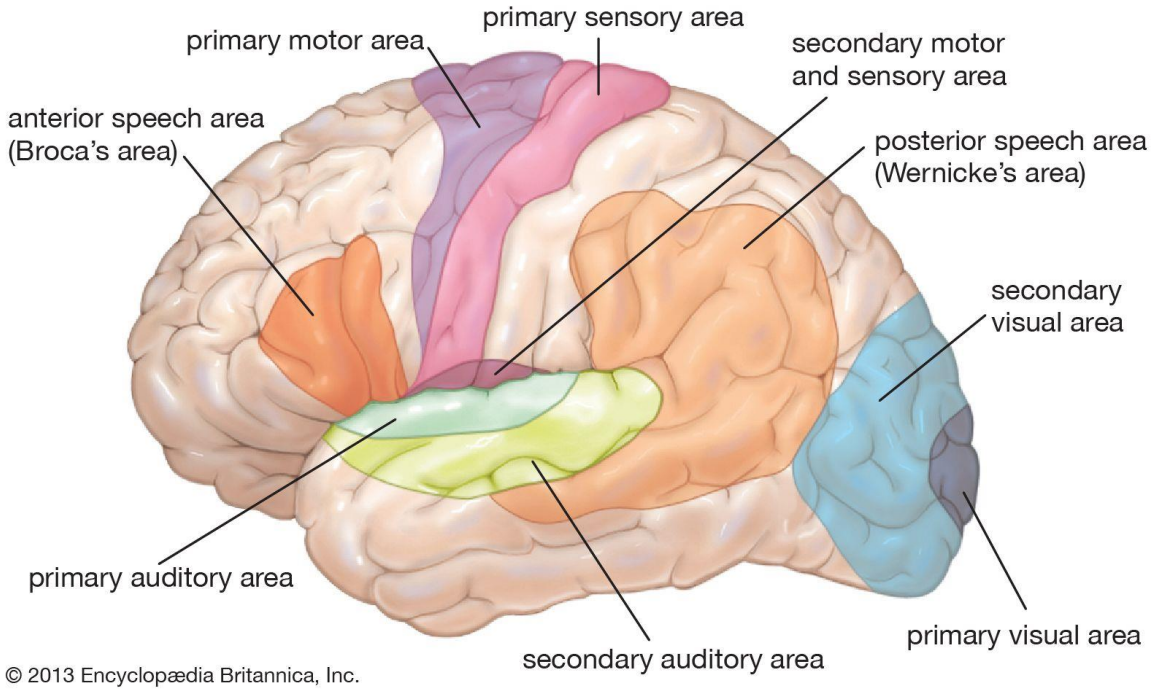
- **Phoneme**: the smallest unit of speech sound
- **Morpheme**: the smallest unit that signifies meaning
- **Syntax**: the complex abstract regularities (rules) in how to order words/phonemes
- **Mental lexicon**: the collective store of information about semantics (meaning), syntax, orthography (writing), and phonology (sounds) of words
- **Phonemes** combine to form **morphemes**, which are governed by **syntax**, all of which are stored and accessed in the **mental lexicon**



Neuroanatomy of Language

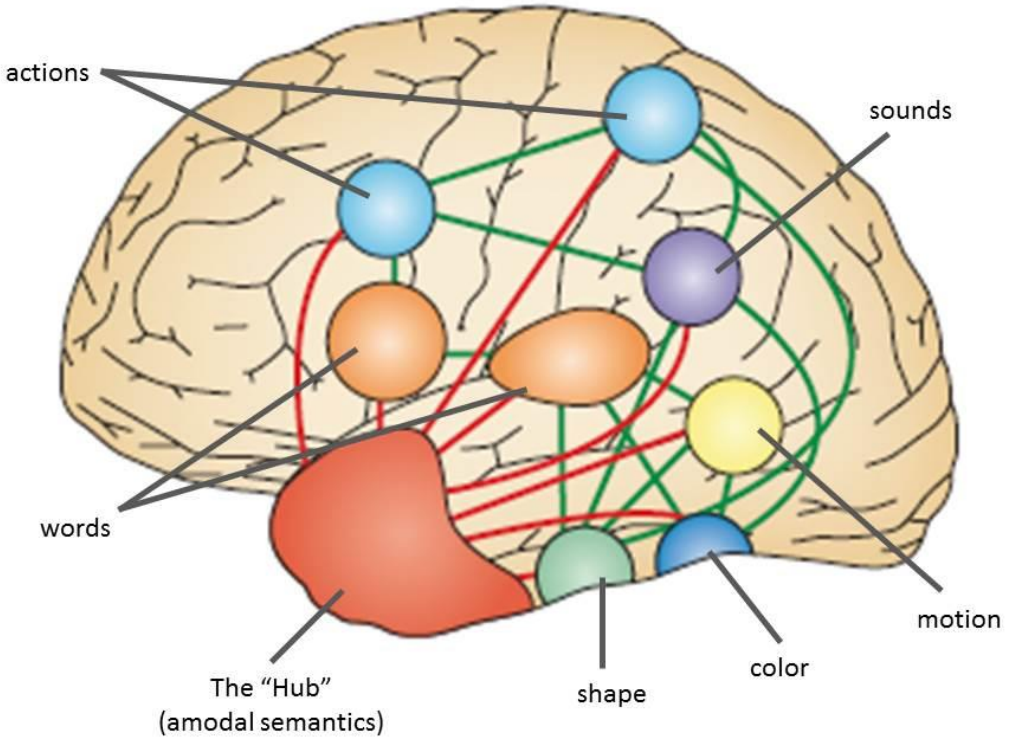


- On the **left hemisphere**:
- **Broca's area**: language production, speech planning, syntactic processing
  - Broca's aphasia (expressive aphasia): cannot produce syntactically correct speech output, but may be able to produce semantically correct words with some effort
- **Wernicke's area**: understanding language, meaning and semantics
  - Wernicke's aphasia (receptive aphasia) can produce fluent, syntactically correct speech, but it will be devoid of semantic content



The hub and spoke model

- The **anterior temporal lobe (ATL)** acts as the **hub**, integrating information across all modalities to create a central, **amodal** (non-sensory-specific) semantic representation
- The **spokes** represent **modality-specific** areas that process different types of sensory/perceptual information
  - Actions, sounds, motion, shape, color, words
- The hub consolidates understanding into abstract meaning, with the spokes contributing their sensory-specific information to the system

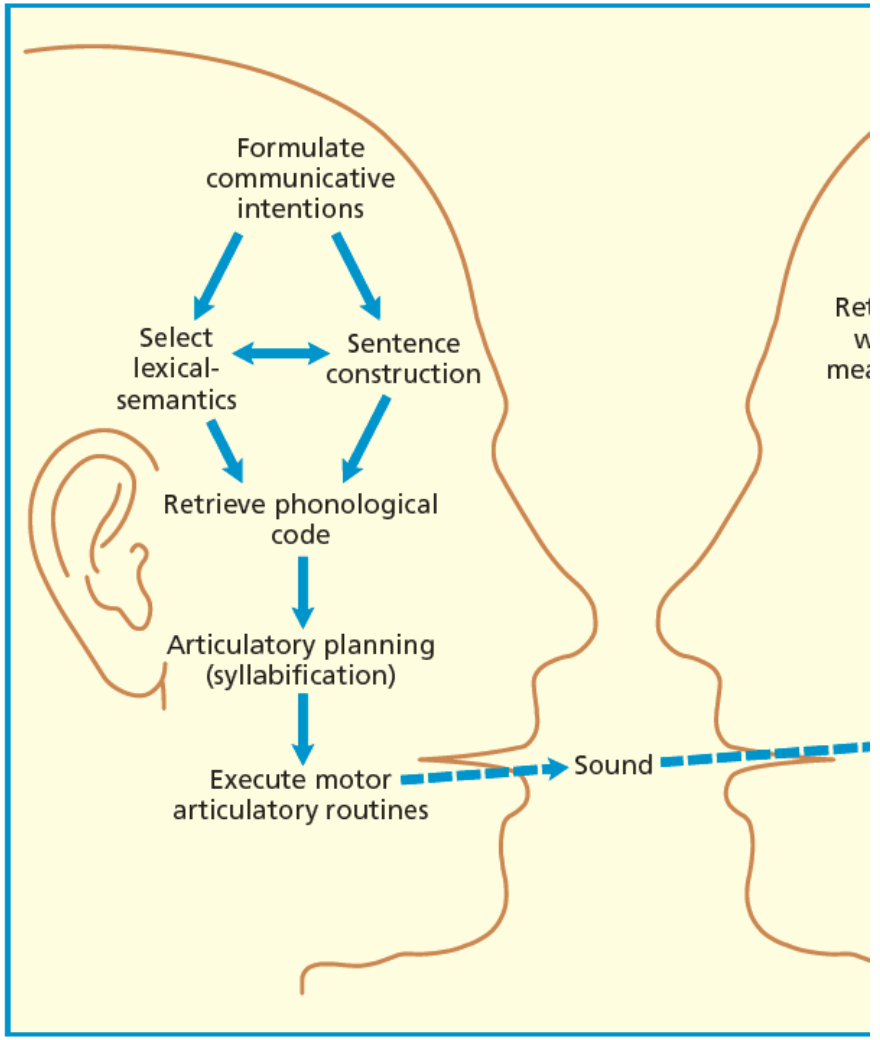


What about the right hemisphere?

- **Broca's area** is responsible for language producing, speech planning, and grammar. The equivalent region on the right is involved in **prosody** of speech – rhythm, stress, intonation patterns that help convey subtleties of emphasis and emotion
- **Wernicke's area** is responsible for understanding and processing speech. The equivalent region on the right is involved in interpreting **emotional tone** and content of speech
- Right hemisphere activity is critical for understanding **metaphors**, **idioms**, **symbolic language**, emotional and contextual **nuance**, **humor**, **irony**, **sarcasm**, and **indirect** language
- Pure left hemisphere language is more literal and syntactical, while right hemisphere activity allows for understanding of deeper, more complex meaning and figurative expression

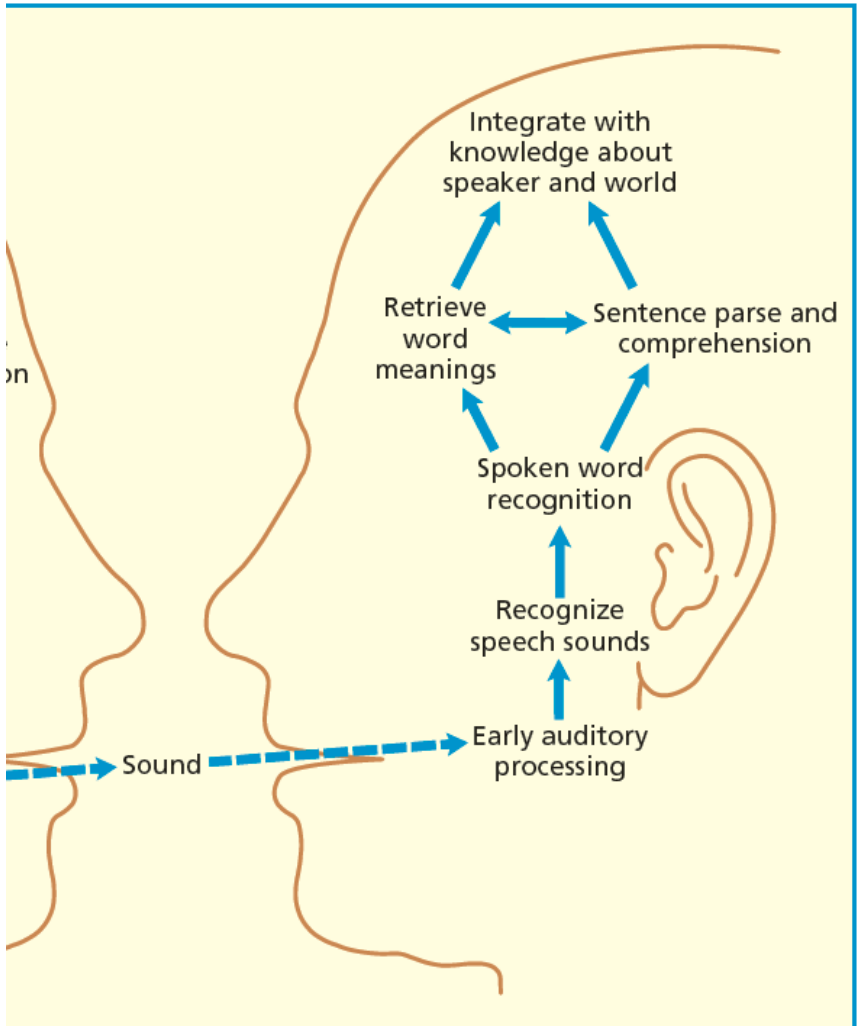
Stages of speech production

- Intent formulated in higher-level networks, **prefrontal cortex**, **ACC**
- **Lexical semantics** and sentence construction in **Broca's area**, **middle temporal lobe**, **ACC**
- **Phonemes** retrieved from auditory processing regions
- **Articulatory planning** in **Broca's area** and **premotor cortex**
- Expression out of **motor** system



Stages of speech comprehension

- **Primary auditory cortex** processing incoming sound waves
- **Superior temporal gyrus and sulcus** recognize sound as **phonemes** and speech
- **Wernicke's area** and left middle temporal gyrus match sounds to **mental lexicon**
- **Wernicke's area** and other connected regions process meaning and parse syntactical structure
- Higher-level networks and prefrontal cortex integrate language information with social, contextual, and world knowledge to have an integrated understanding



Critical Period in Language Learning

- **Critical period**: a limited developmental window in which the brain is highly plastic and receptive to acquiring language, during early childhood (broadly birth to puberty)
  - Increase in sex hormones during puberty is believed to contribute to the closure of the critical period
- Young language learners recruit a wider range of neural areas when they are learning a language, compared to the more specialized and localized processing seen in adults
- Children initially have the ability to hear and make all the possible phonemes that are observed across cultures, and they go through **synaptic pruning** to use only the ones necessary for their native language
- Left hemisphere dominance for language processing emerges during the critical period, but it does not become as fixed until the window closes