NEUROPHONETICS

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WHAT IS NEUROPHONETICS?

"Neurophonetics deals with neurogenic impairments of the motor act of speaking and of the perceptual processes of spoken language understanding, with the aim of unravelling the neural organization of speech motor control and speech perception."

(Ziegler 2008: 491)

"Neurophonetics aims at the elucidation of the brain mechanisms underlying speech communication in our species"

(Hertrich & Ackermann 2013)

''To the extent that phonetics is a subdiscipline of linguistics, neurophonetics can be viewed as a subdiscipline of neurolinguistics''

(Ziegler 2008)

LECTURE OUTLINE

1. Anatomy & Physiology of the Brain
2. The WLG Model
3. Modern Advances
    a. Where?
    b. How?
4. Conclusion

WARNING SLIDE

There will be some bloody(ish) images

ANATOMY AND PHYSIOLOGY OF THE BRAIN

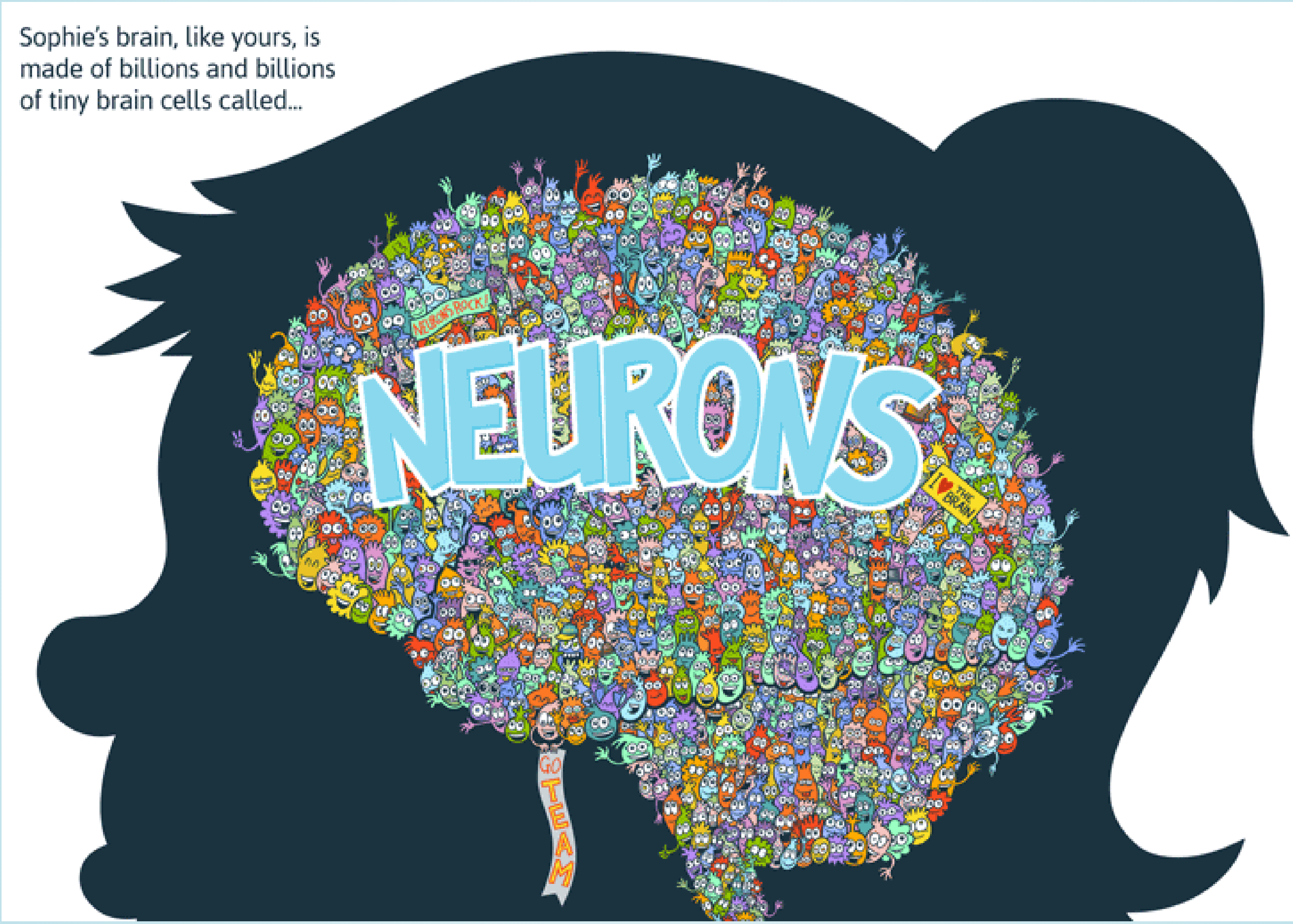


Illustration for Ned the Neuron, published by Kizoom in 2012.

The brain is made of NEURONS and GLIAL CELLS (but glial cells are not discussed here)

NEURONS are arranged into layers which allow for the efficient transfer of information, carried as electrical impulses

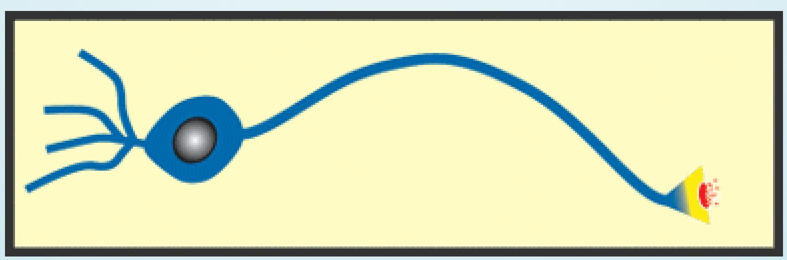
NEURONAL LAYERS in different areas are arranged to maximise processing efficiency for the functions that they are required to perform and provide the basis for the larger structures of the brain

NEURONS

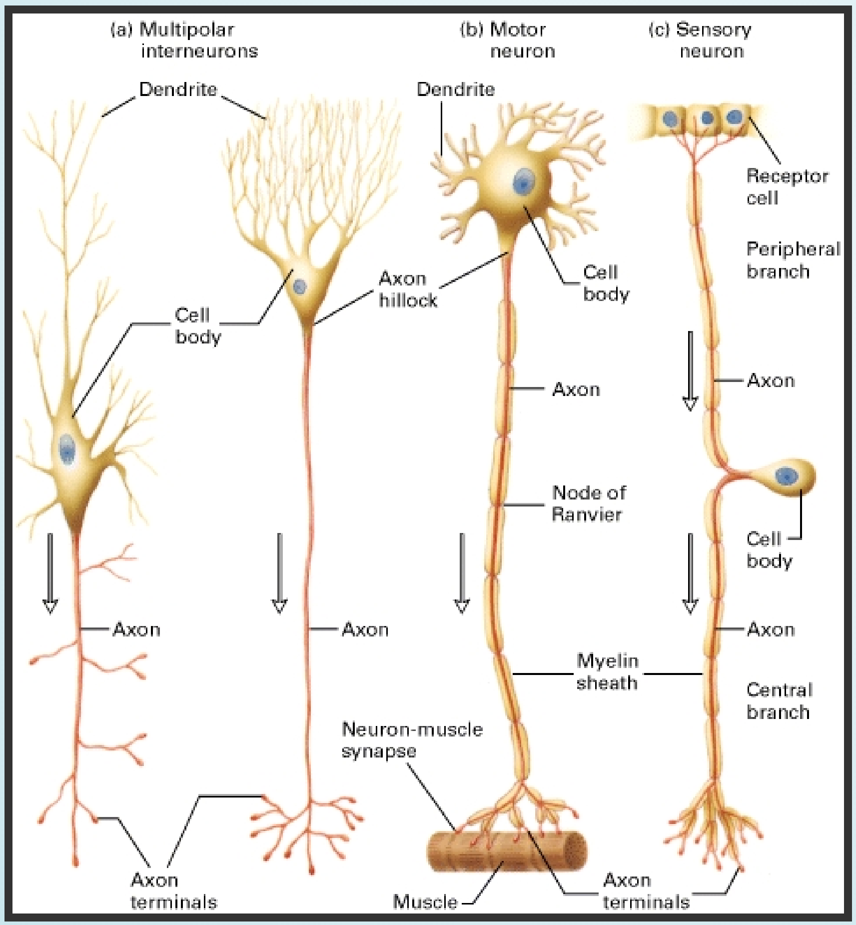
Neurons transmit information to other neurons or muscles (via the brain stem)

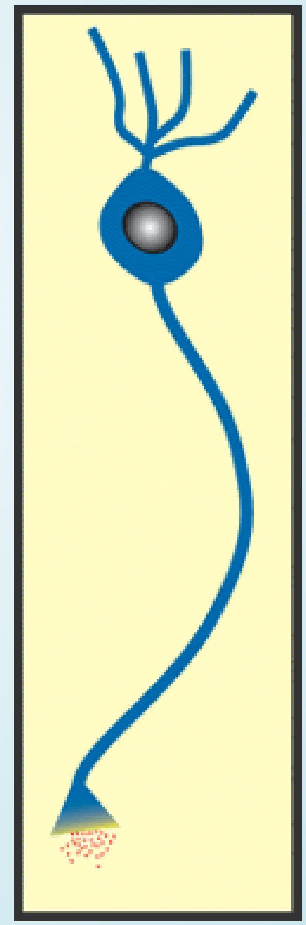
FIRING: electrical ACTION POTENTIAL travels down AXON to SYNAPSE (junction)

A NEUROTRANSMITTER is released which either EXCITES or INHIBITS the post-synaptic cell



MYELIN encases important connections, both to protect vital information transfer routes and to speed up transmission of the action potential



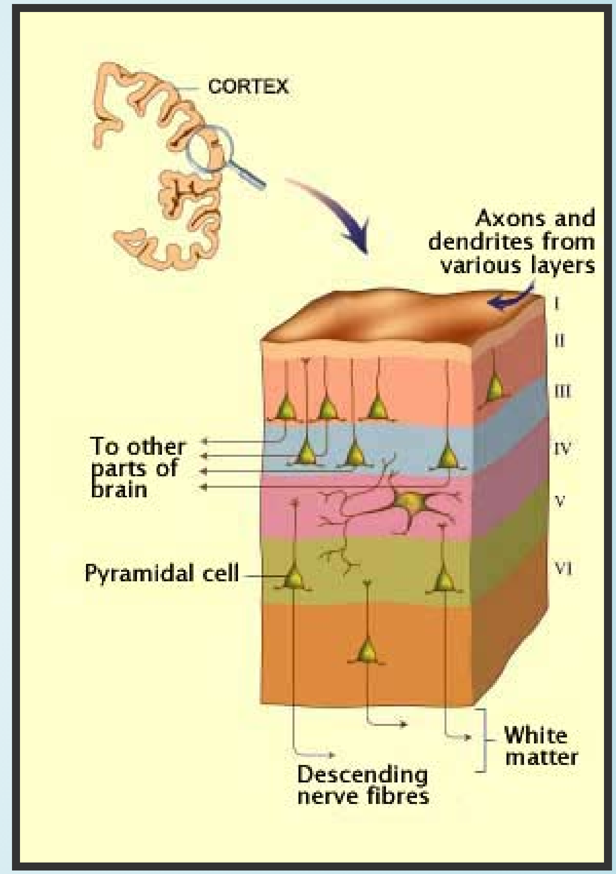


Web source 1.

NEURONAL LAYERS

Neurons are arranged into layers specific to the functions that they are required to perform

Neurons that perform similar functions are LOCALISED to a particular region of the brain



Web source 2.

BRAIN STRUCTURE

GENES TO COGNITION ONLINE

www.g2conline.org

THE CEREBRUM

Cerebrum = 2 hemispheres

Each hemisphere is divided into 4 lobes:

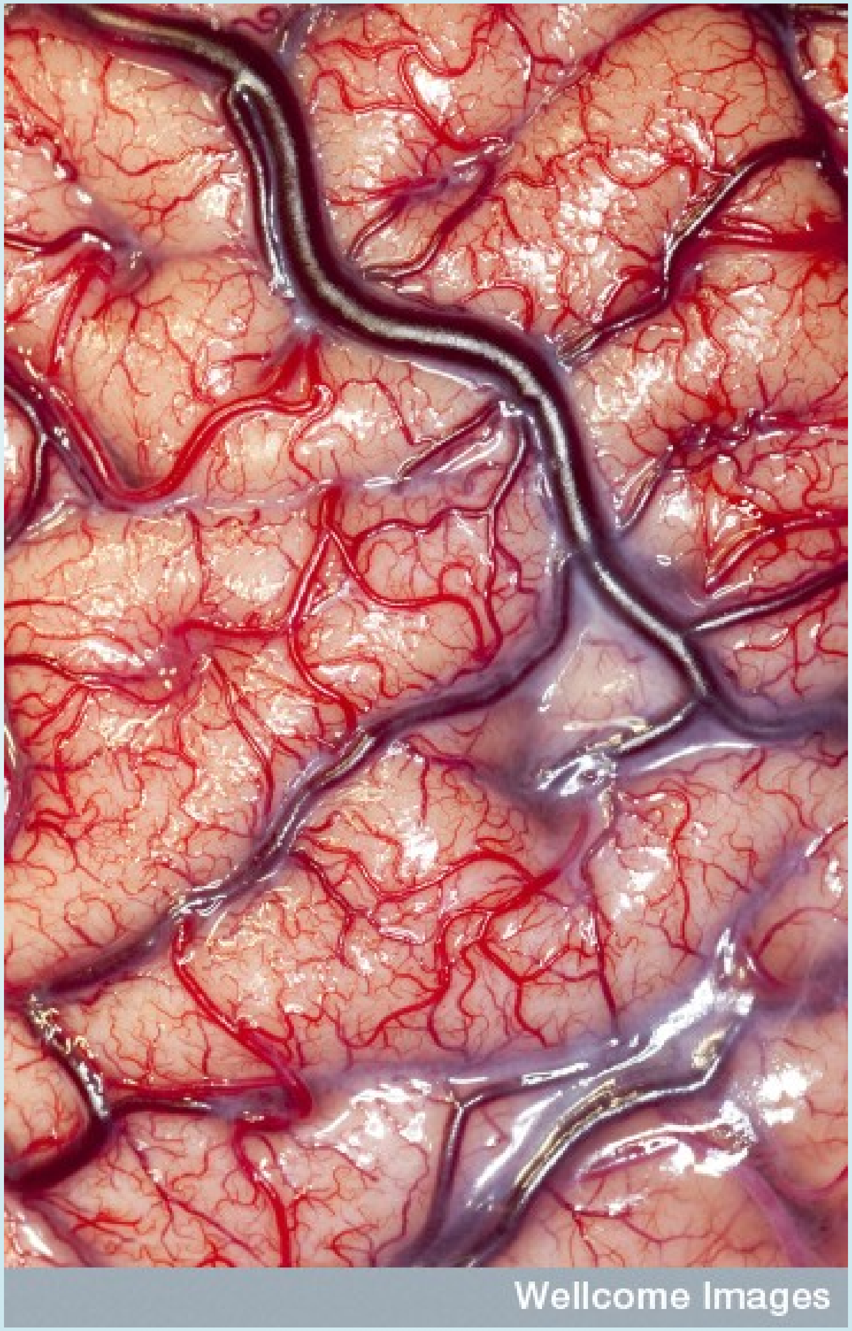
- Frontal
- Parietal
- Temporal
- Occipital

THE CEREBRAL CORTEX

Cerebral cortex = surface of cerebrum

Cortex can be roughly divided into areas of functions

e.g. language, personality, vision, audition, motor and sensory functions



Photograph by Robert Ludlow. Wellcome Trust Image Awards winner 2012.

LEFT & RIGHT HEMISPHERES

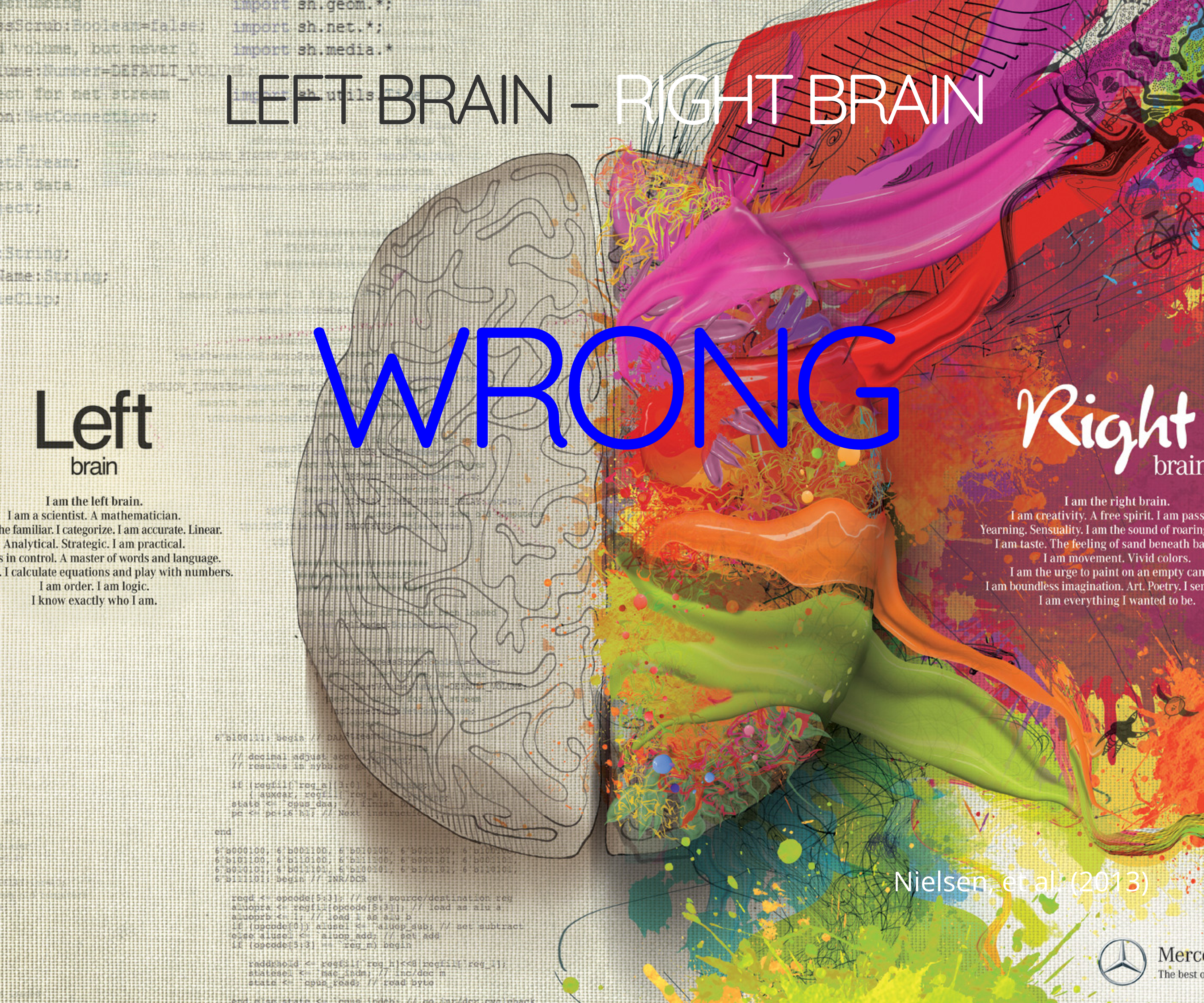
Equal size/proportion, but different white/grey matter structures

Different networks of connectivity

Some functions are the same:

MOVEMENT SENSATION	Planning & execution cross sides

However, some functions are different across the two hemispheres…


LEFT BRAIN – RIGHT BRAIN
WRONG
Left
brain
I am the left brain.
I am a scientist. A mathematician.
he familiar. I categorize. I am accurate. Linear.
Analytical. Strategic. I am practical.
s in control. A master of words and language.
. I calculate equations and play with numbers.
I am order. I am logic.
I know exactly who I am.
Right
brain
I am the right brain.
I am creativity. A free spirit. I am pass
Yearning. Sensuality. I am the sound of roarin
I am taste. The feeling of sand beneath ba
I am movement. Vivid colors.
I am the urge to paint on an empty can
I am boundless imagination. Art. Poetry. I se
I am everything I wanted to be.
Nielsen, et al. (2013)

HEMISPHERIC FUNCTIONS

Each hemisphere has specific processing strengths, eg:

Left Hemisphere	Right Hemisphere
Important for language processing, mathematical functioning	Important for processing visual and spatial information
(Hervé, et al. 2013, Jolles et al. 2015)	(Hervé, et al. 2013)

WITHIN THE CEREBRUM

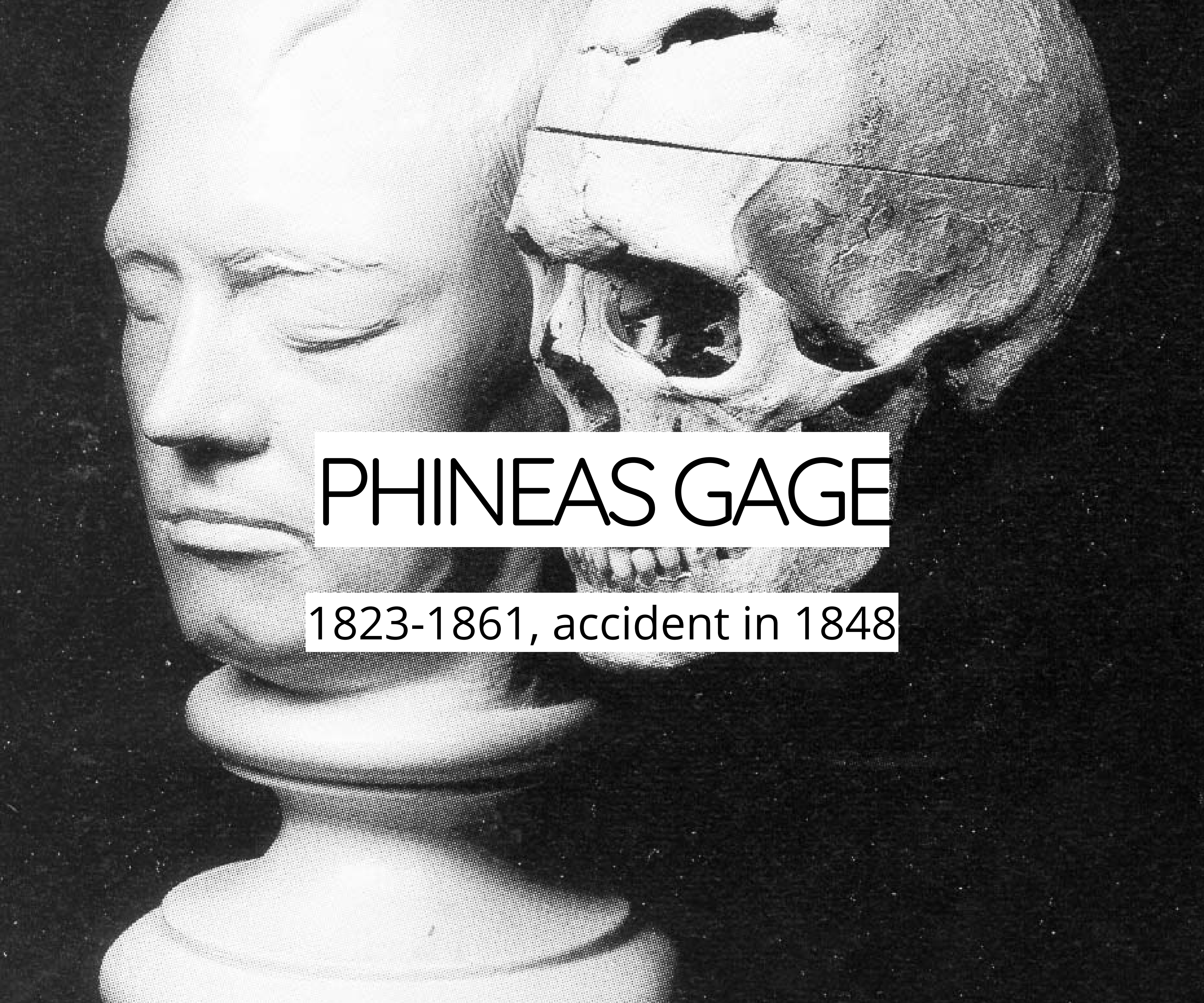
CORTEX (CEREBRUM SURFACE):

- Grey matter (nerve cell bodies)
- Some white matter

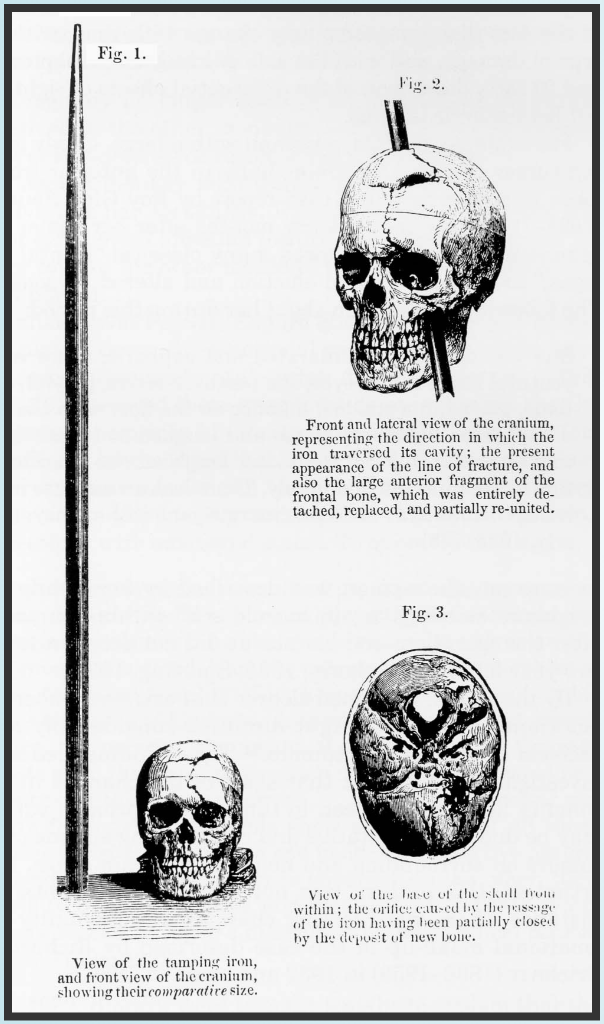
SUBCORTICAL AREAS:

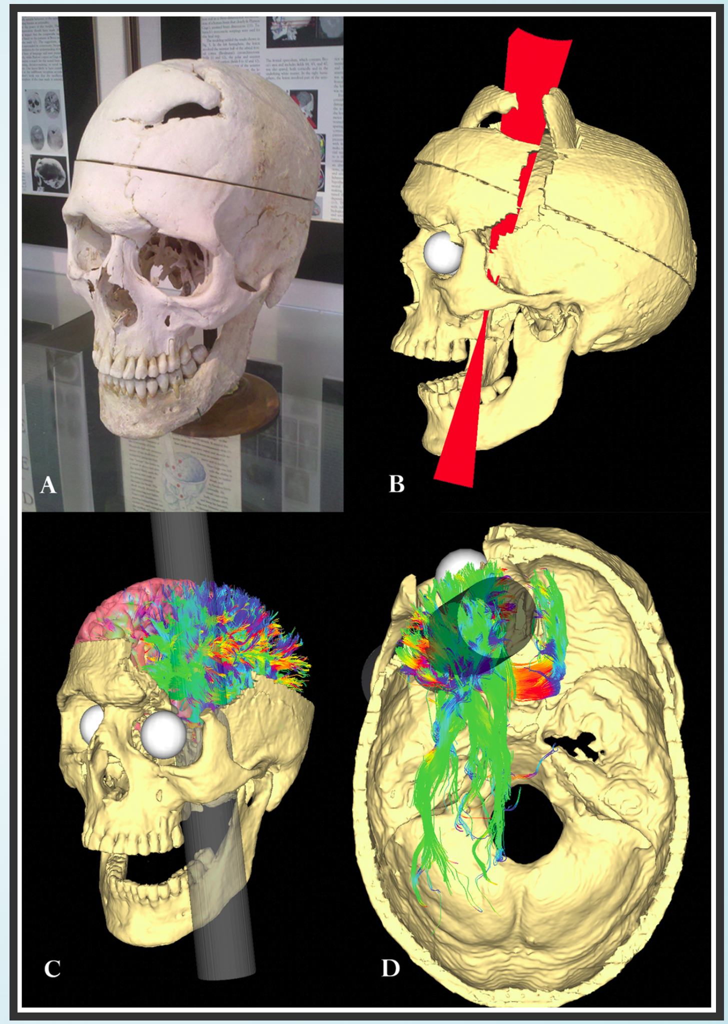
- Grey matter
- White matter fibres (eg.):
  - Corpus Callosum (connects right and left hemispheres)
  - Arcuate Fasciculus
    (connects motor and sensory cortices)

THE WLG MODEL


PHINEAS GAGE
1823-1861, accident in 1848

PHINEAS GAGE (1848)





Van Horn (2012)

PHINEAS GAGE (1848)

TRAUMA TO FRONTAL LOBE

One of first cases to highlight role of frontal lobe in:

- Personality
- Emotional regulation
- Decision making / Problem solving

WHAT DOES THIS SUGGEST?

- Specific brain functions are grouped in specialised regions
- We say that brain function is LOCALISED

BRAIN PATHOLOGY AND LANGUAGE

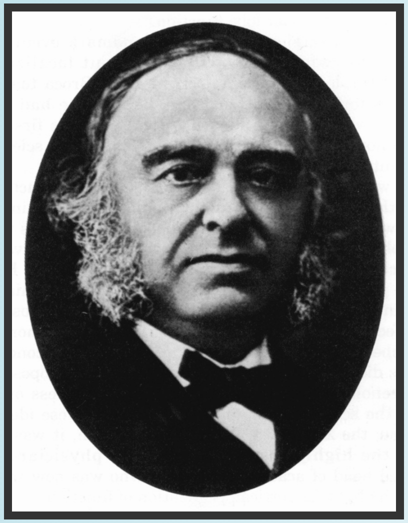
Aphasia:

Loss or impairment of the ability to produce or comprehend language, due to brain damage

Various types:

- Global
- Broca’s/motor
- Wernicke’s/jargon/anomic

BROCA & WERNICKE

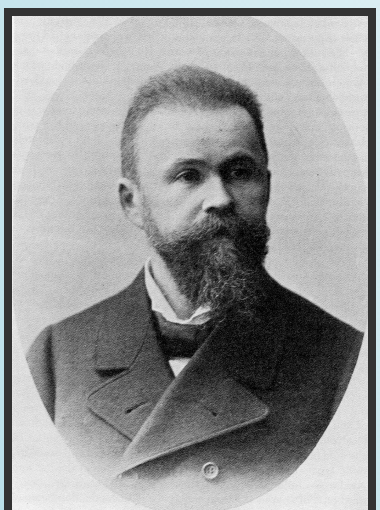


Paul Broca (1824-1880)

Broca’s patient, ‘Tan’ – 1861:

Problem with production (only one syllable ‘tan’)

Large cyst in the left hemisphere (“mushy and deformed”)



Karl Wernicke (1848-1905)

Wernicke’s patient – 1874:

Patient who could speak but couldn’t comprehend language

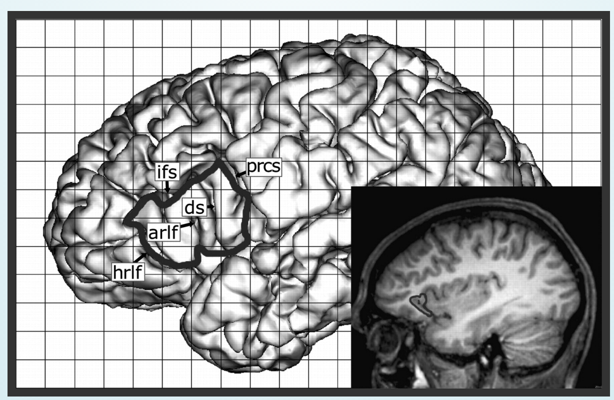
Lesion at the crossroads of 2 lobes of the brain

BROCA'S AREA

WHERE?

Frontal lobe - Inferior frontal gyrus

- Pars opercularis
- Pars triangularis



Anwander, et al. (2007)

BROCA'S APHASIA

FUNCTION

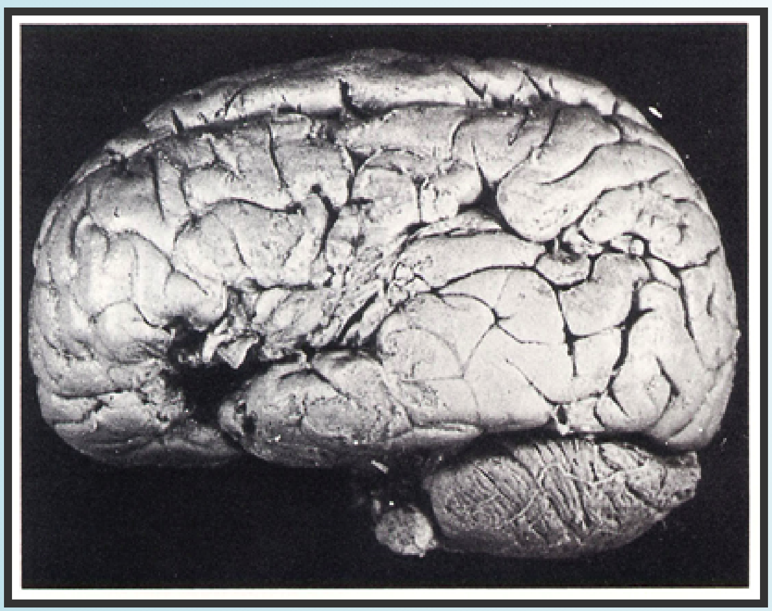
- Motor language area
- Expression

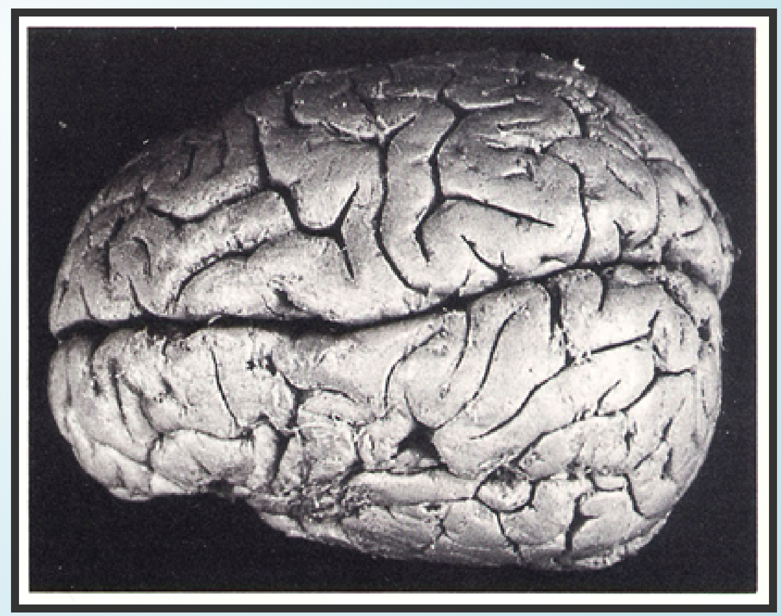
APHASIA

- Motor / non-fluent aphasia
- Good comprehension, no/impaired speech
- E.G. 'boy go store' vs 'The boy has gone to the store'
- Slow, laboured, ungrammatical speech
- "yes…ah…Monday…ah…dad and…and…ah…hospital….and ah….Wednesday….Wednesday"

BROCA'S AREA

Photograph of the brain of Paul Broca's patient called "Tan"



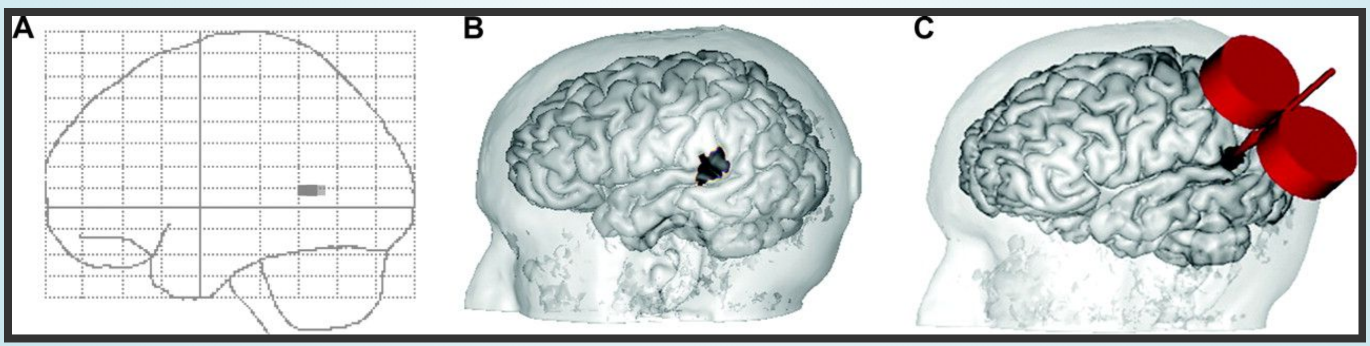


WERNICKE'S AREA

WHERE?

Temporal/Parietal lobe

- Supramaringal gyrus
- Angular gyrus



Andoh, et al. (2008)

WERNICKE'S APHASIAS

FUNCTION

- Sensory language area
- Comprehension

APHASIA

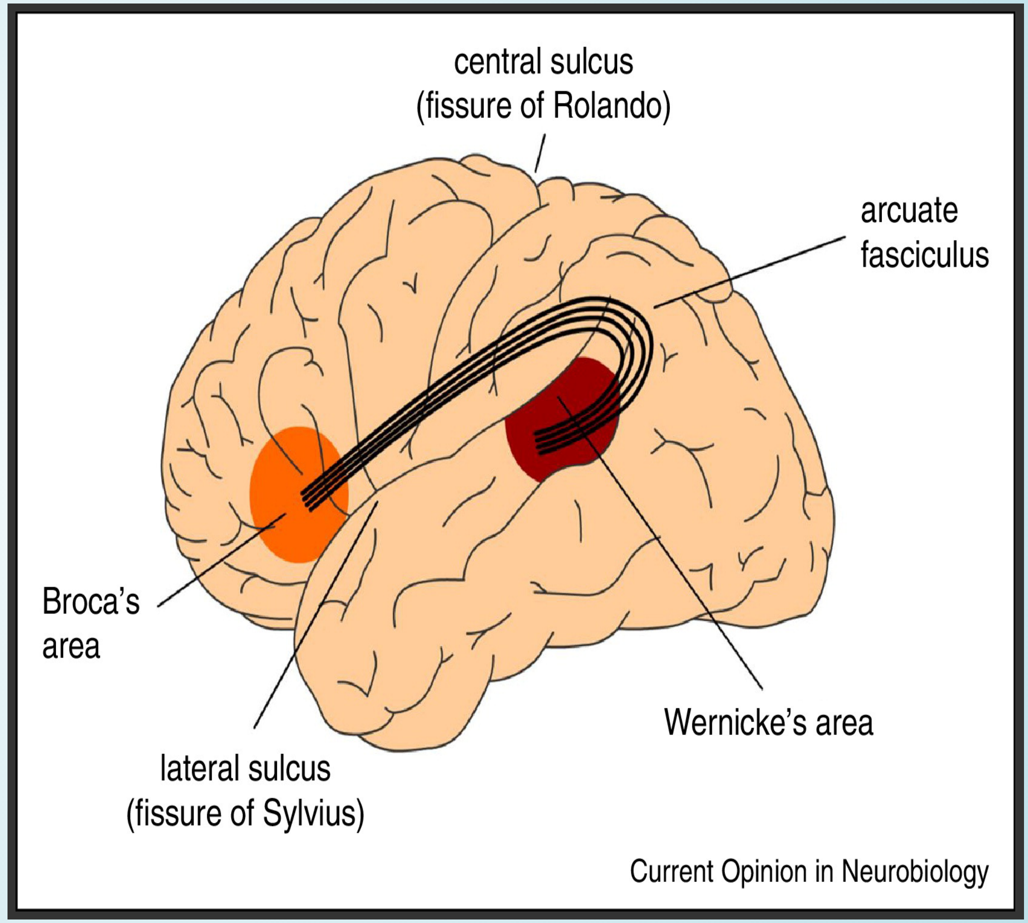
- Fluent / Receptive (cortical sensory) aphasia
- Defect in comprehension, good spontaneous speech
- Anomic aphasia - word finding difficulty
  - Slow, laboured, ungrammatical speech
  - Jargon aphasia - fluent, but unintelligible jargon

THE WLG MODEL

Broca's and Wernicke's areas are connected via the ARCUATE FASCICULUS

This view was dominant for more than a century and still carries weight today

It is known as the Wernicke-Lichtheim-Gerschwind Model (WLG model), named after those that helped to develop it



Hagoort (2014)

SUMMARY

- Broca's area
  - Inferior frontal gyrus (frontal lobe)
  - Good comprehension but impaired speech
  - Seat of language production(?)
- Wernicke's area
  - Supramaringal/angular gyrus (temporal/parietal lobe)
  - Good production but defect in comprehension
  - Seat of language comprehension(?)
- Both localised to left hemisphere
- They operate together as part of a larger network

MODERN ADVANCES

WHERE?

CLASSIC NEUROIMAGING EVIDENCE ABOUT LANGUAGE PROCESSING

SCOTT, ET AL (2000)

Normal Speech (Sp)

0:00 / 0:01

Spectrally Rotated Speech (RSp)

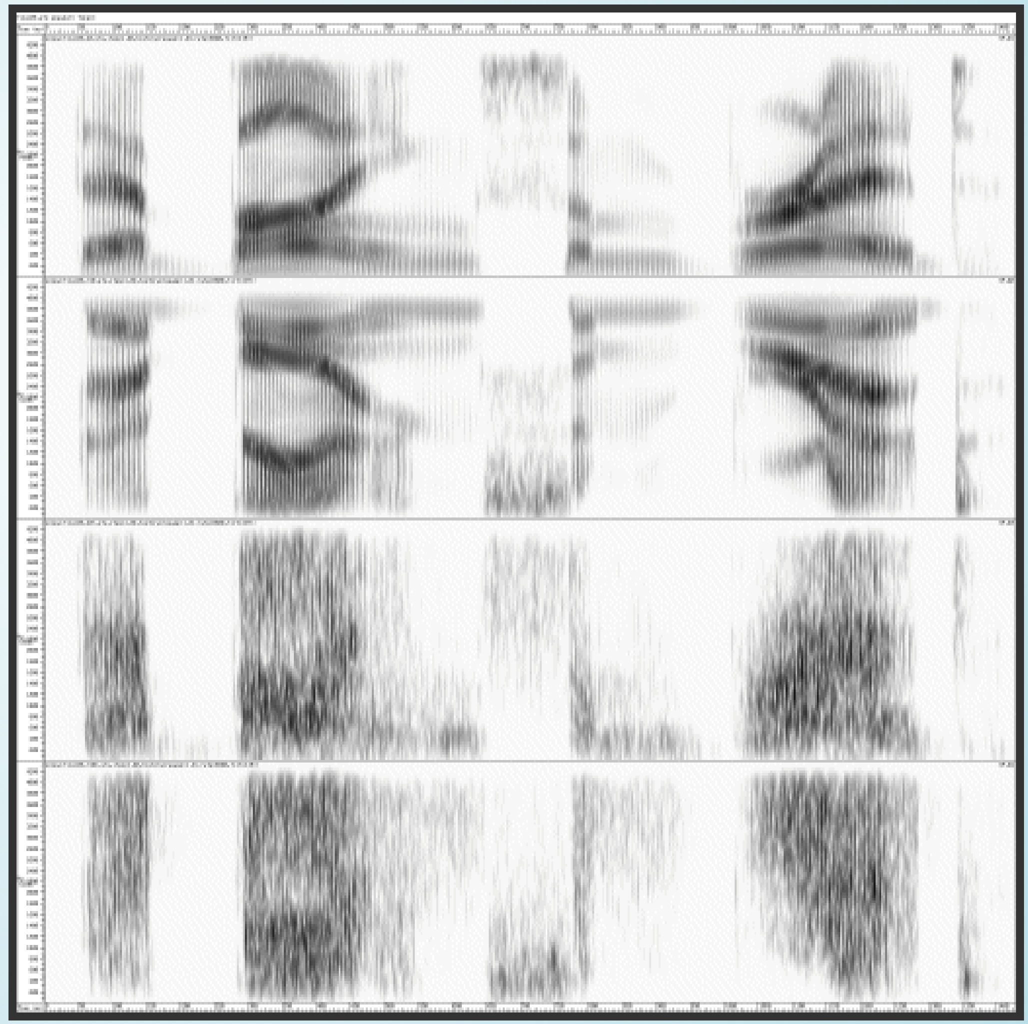
0:00 / 0:01

Vocoded Speech (VCo)

0:00 / 0:01

Rotated vocoded Speech (RVCo)

0:00 / 0:01



CLASSIC NEUROIMAGING EVIDENCE ABOUT LANGUAGE PROCESSING

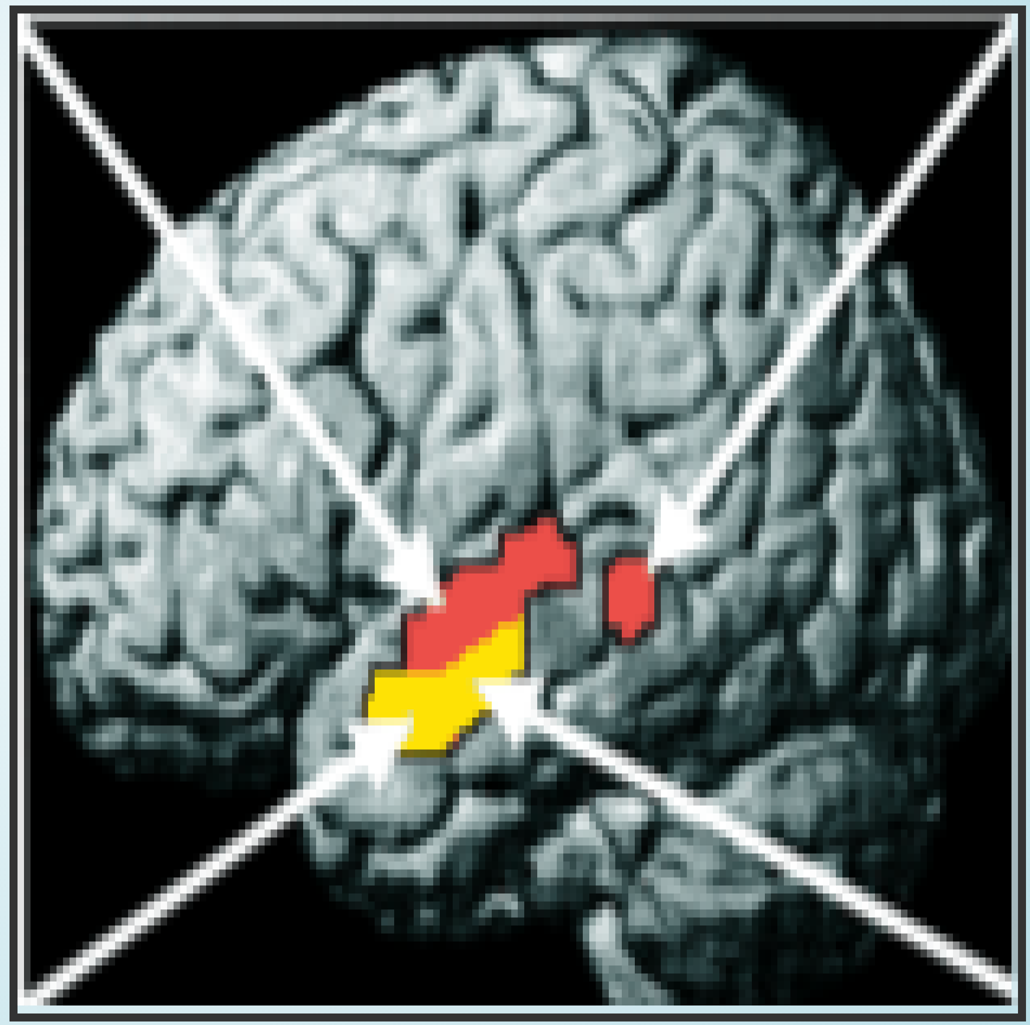
SCOTT, ET AL (2000)

Red = Responses to sounds with phonetic information

ie. Sp, RSp & VCo

Yellow = Responses to sounds that are intelligible

ie. Sp & VCo

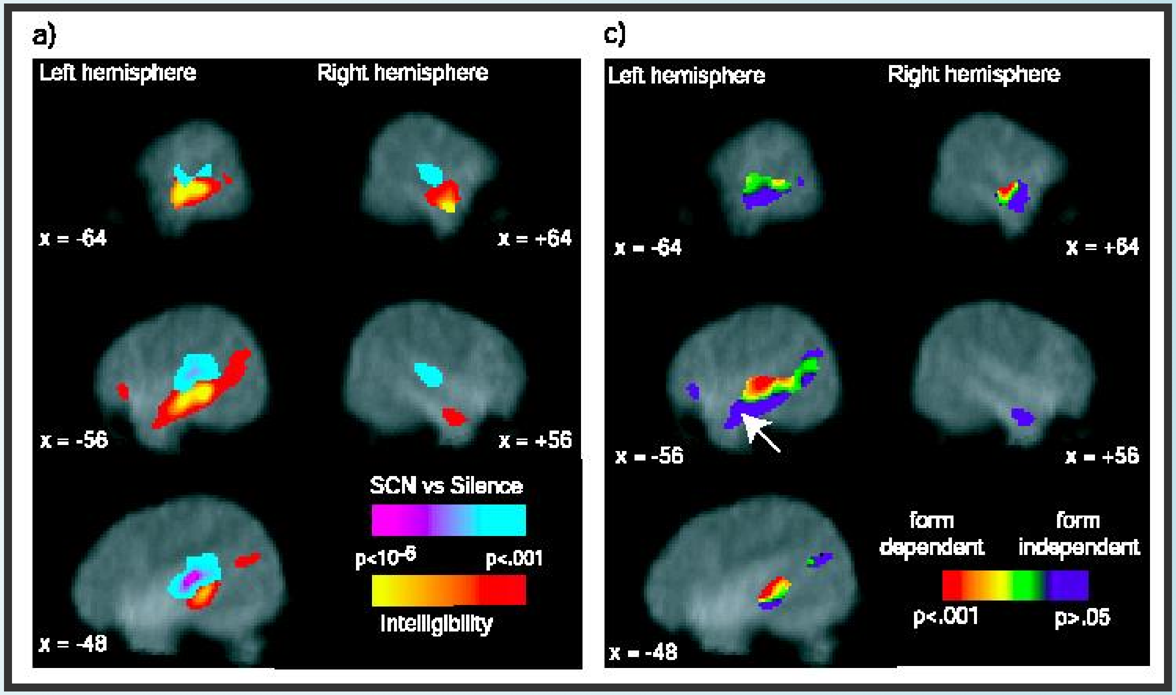


CLASSIC NEUROIMAGING EVIDENCE ABOUT LANGUAGE PROCESSING

DAVIS & JOHNSRUDE (2003)

English sentences, distorted in a variety of ways.

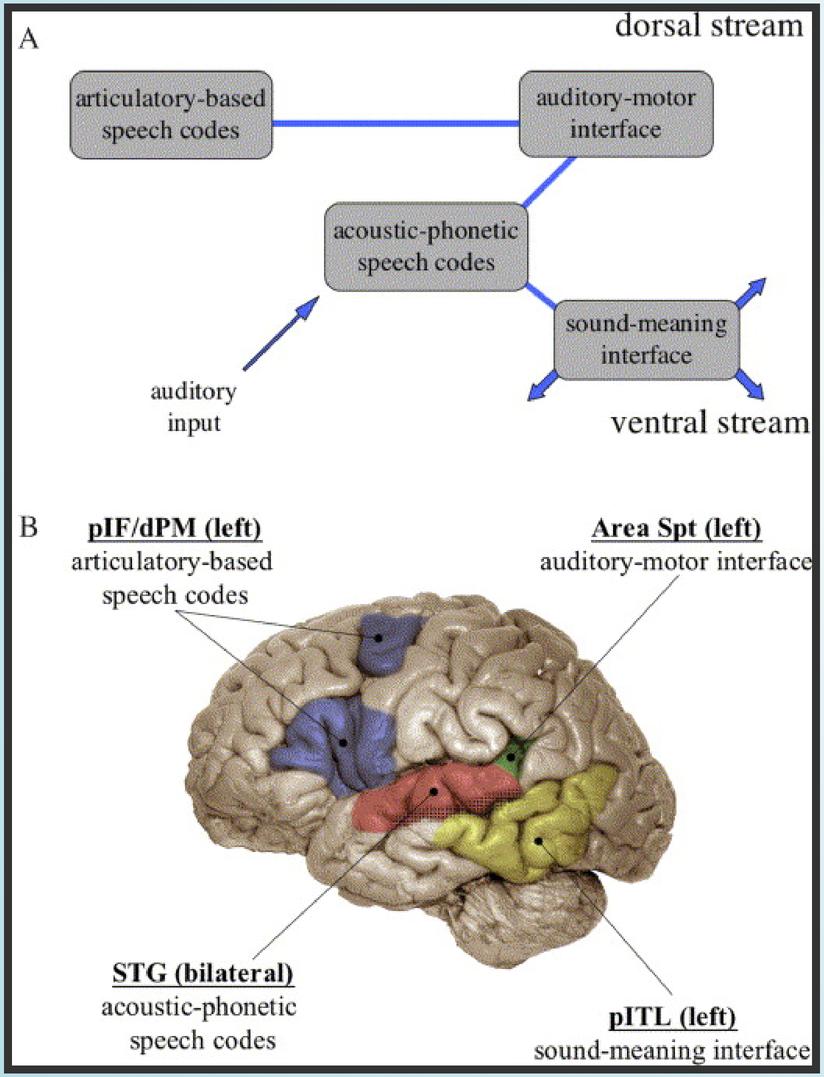
Looked for correlations between blood flow and intelligibility of speech sounds



Left: intelligible speech vs noise

Right: responses to different forms of distortion

CLASSIC NEUROIMAGING EVIDENCE ABOUT LANGUAGE PROCESSING



Hickock & Poeppel (2004)

Superior Temporal Gyrus

- Bilateral (both hemispheres)
- Acoustic-phonetic forms

Dorsal Stream (left only)

- Wernicke’s area
- Broca’s area
- Motor cortex
- Articulatory forms

Ventral Stream (left only)

- Posterior Inferior Temporal Lobe
- Sound-meaning interface

LATERALISATION OF LANGUAGE FUNCTIONS

Left Hemisphere	Right Hemisphere
Traditionally thought to be dominant for language processing Preference for intelligible speech	Damage may spare production and comprehension, but can lead to problems with: pragmatic ability, prosody, speaker characteristics (phonagnosia), recognition of music & environmental sounds
Possibly more sensitive to phonetic form with better time resolution (limited evidence)	Possibly more sensitive to speaker characteristics with better frequency resolution (limited evidence)

Zatorre, et al. (2002); Scott, et al. (2009); Francis & Driscoll (2006); Friederici (2011)

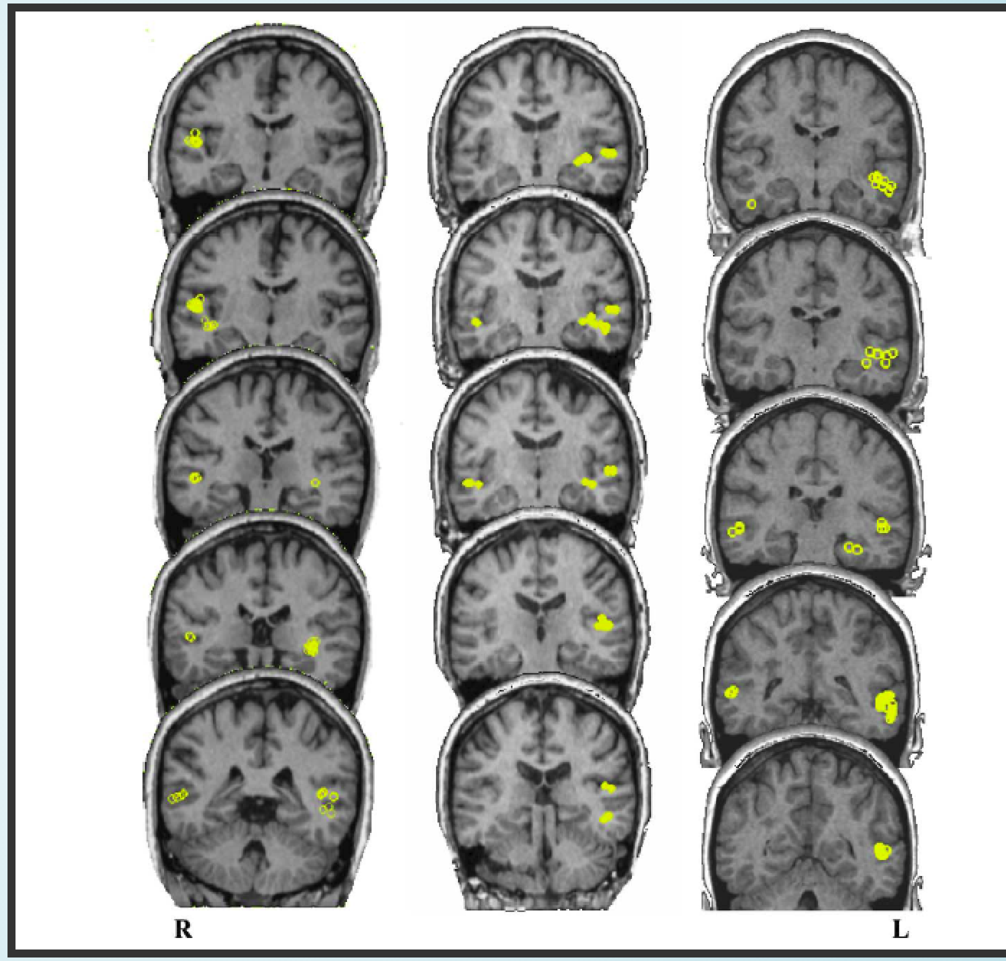
LATERALISATION OF LANGUAGE FUNCTIONS

Spoken word recognition test, was used to establish cerebral dominance

Lateralisation (%Ss):

- Spanish 100% left
- English 80% left
- Chinese 79% bilateral

(tone lang.)

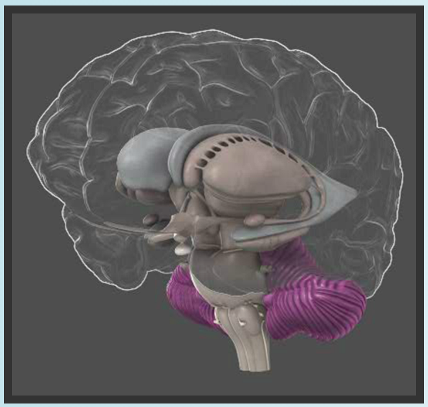


Chinese English Spanish

Valaki et al. (2004)

LANGUAGE PROCESSING BEYOND THE CORTEX

Cerebellum

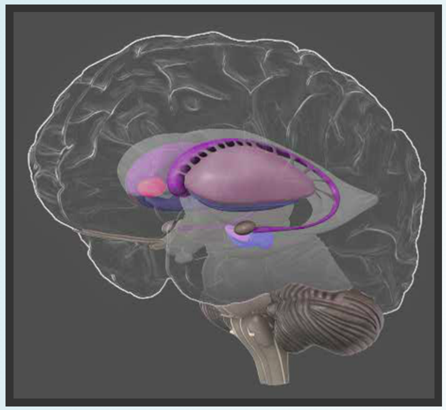


Co-ordinates muscle groups to produce smooth speech & swallowing.

Helps integrate sensory perception and motor output.

Damage can lead to slurring of speech

Basal Ganglia

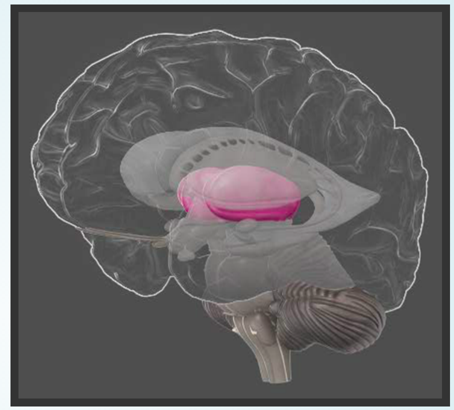


Controls muscles of face, larynx, tongue and pharynx

Damage can lead to lack of coordination and facial expression (e.g. Parkinson’s)

Also disruption to rhythm and temporal processing

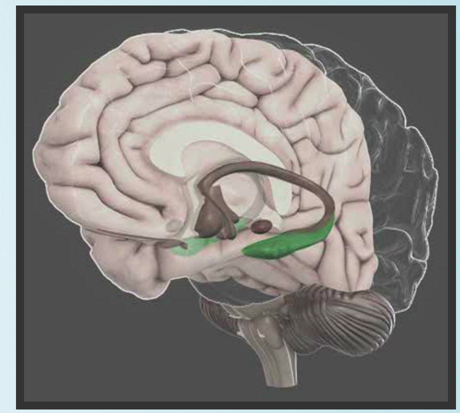
Thalamus



Inner chamber determines which sensory information to forward to cortex

Damage can lead to deficits in memory, attention, reduced spontaneous speech

Hippocampus



Long-term memory, language comprehension, word-generation

Damage (severe in Alzheimer's) can lead to word-finding difficulties

NEURAL CORRELATES OF PHONETIC SKILL

BORN WITH AN EAR FOR DIALECTS?

- In naïve (English) listeners, an individual's brain structure in left auditory cortex, parietal cortex, and left inferior frontal cortex partly predicts their ability to discriminate a difficult contrast (Hindi dental vs. retroflex)

  (Golestani et al., 2002, 2007)

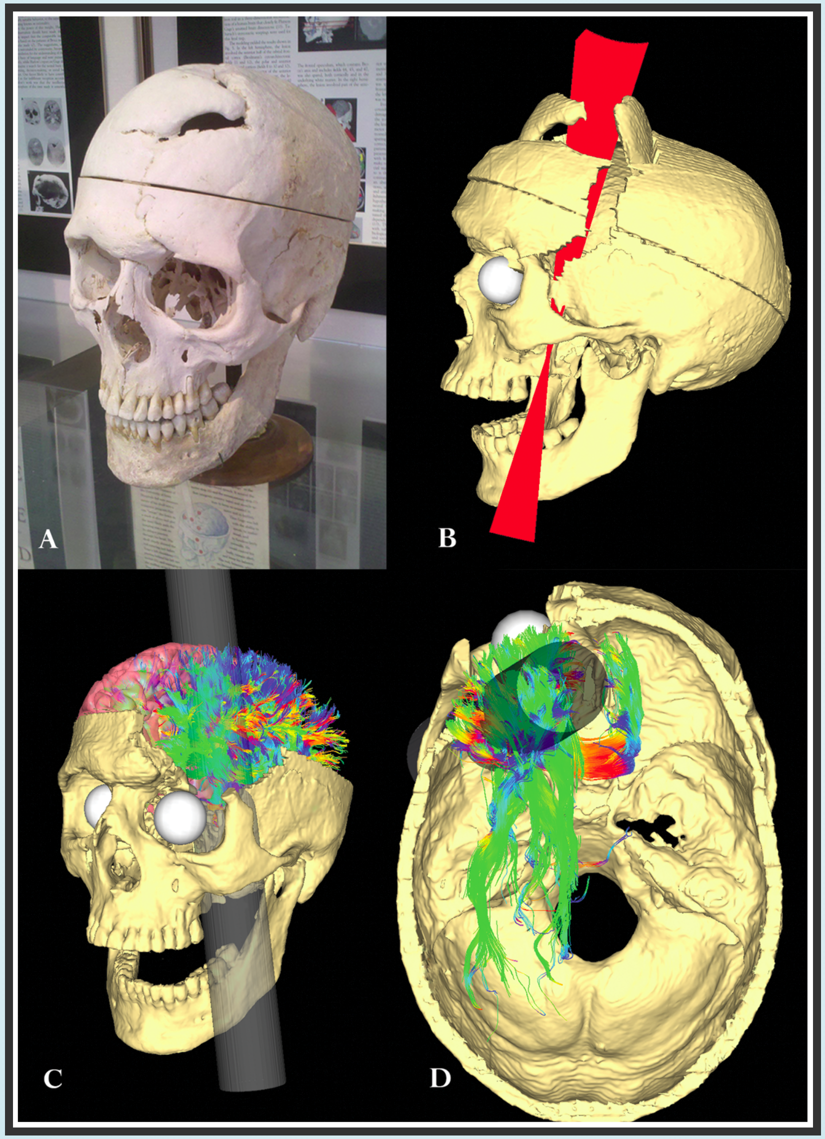
- In phoneticians, years of transcription experience correlate with size of left pars opercularis

  (Golestani et al., 2011)

- Phoneticians are also more likely to have multiple or split left transverse gyri in auditory cortex (thought to develop in utero)

HOW?

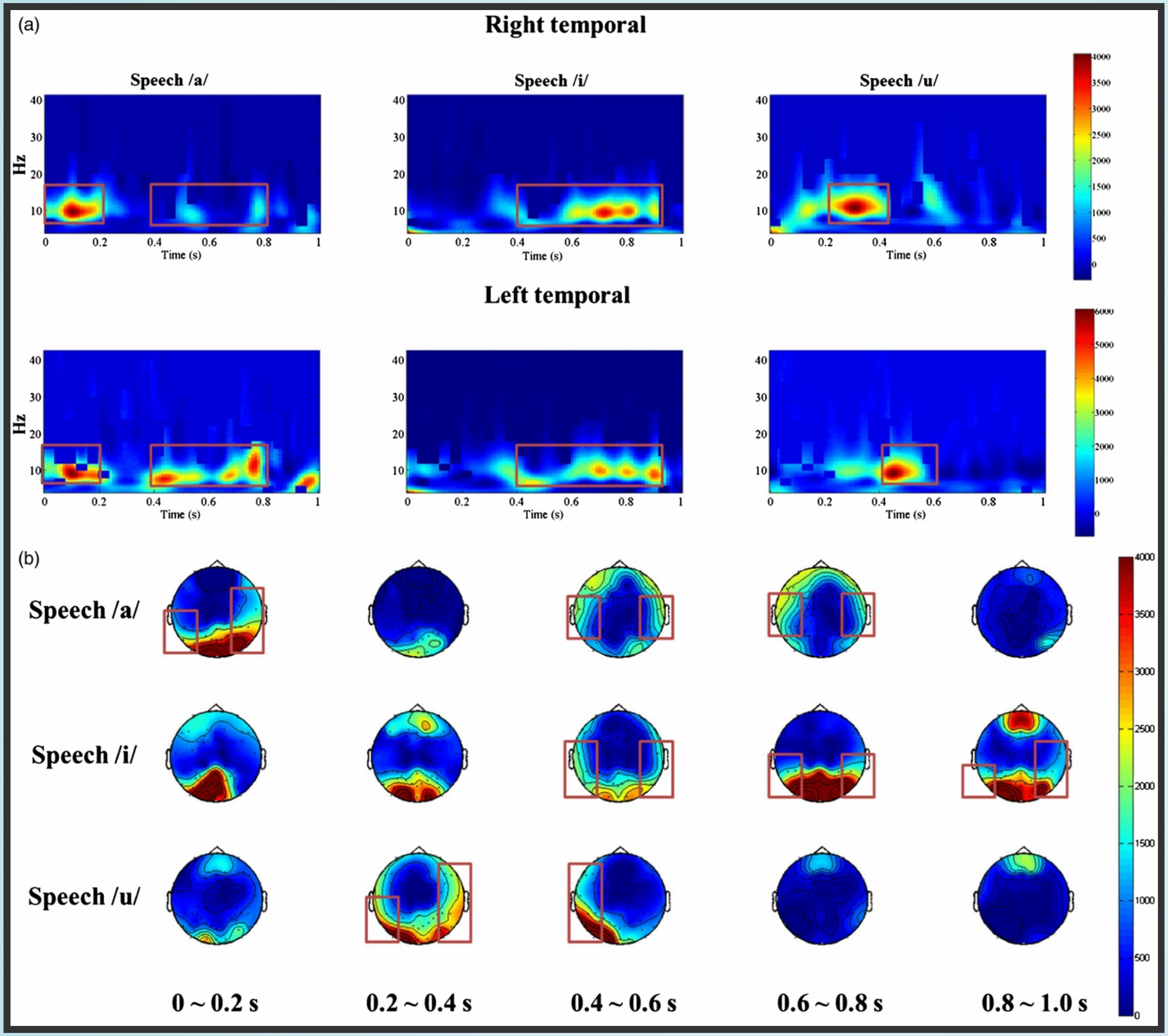
PHINEAS GAGE - MODERN INSIGHTS

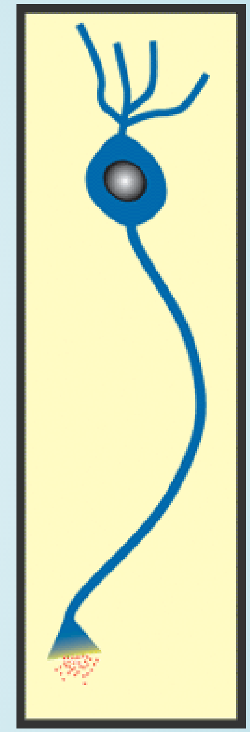


Van Horn, et al. (2012)

Friederici (2011) – Web Link, Firefox & Chrome Only

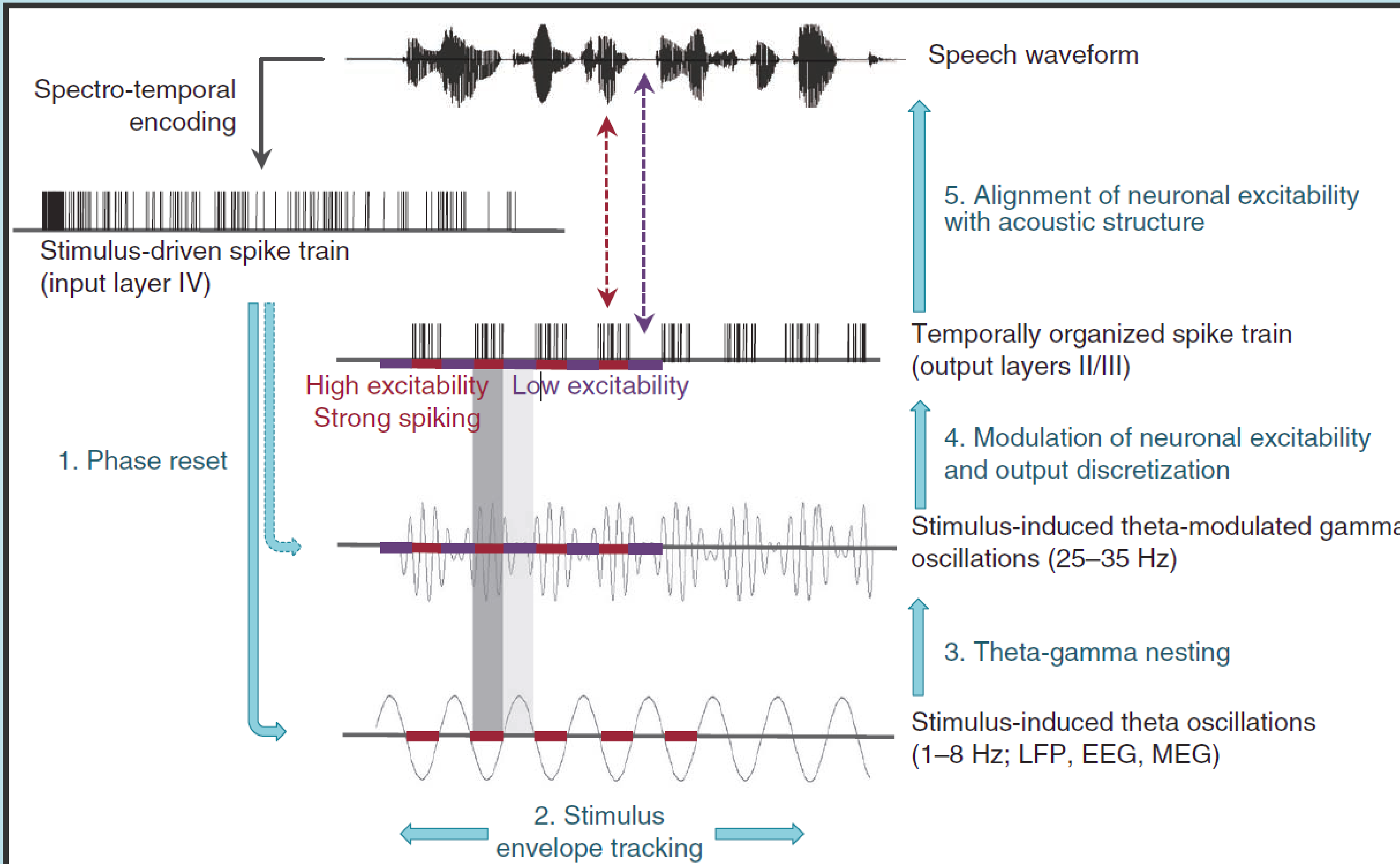
NEURONAL OSCILLATIONS





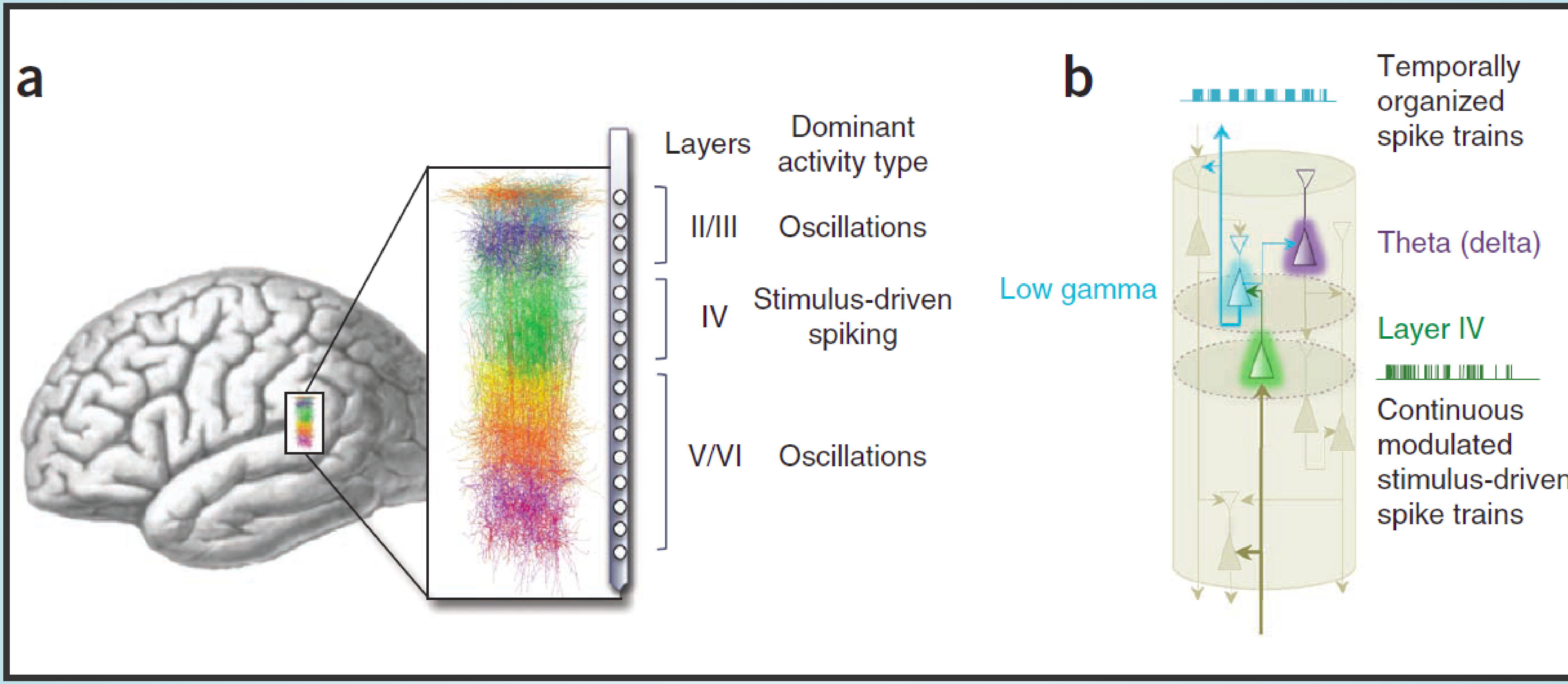
Kim, et al. (2014)

NEURONAL OSCILLATIONS



Giraud & Poeppel (2012)

NEURONAL OSCILLATIONS



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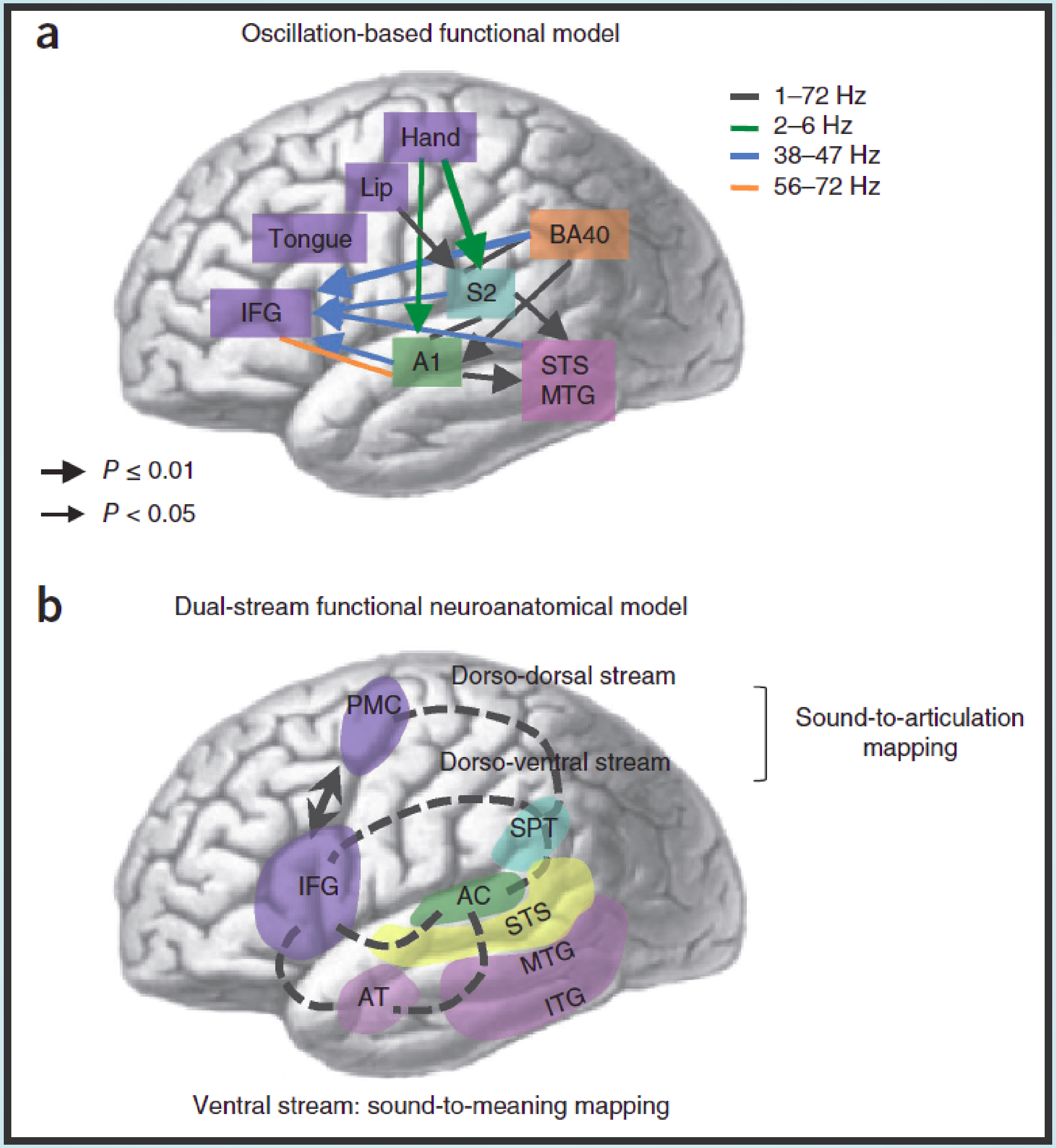
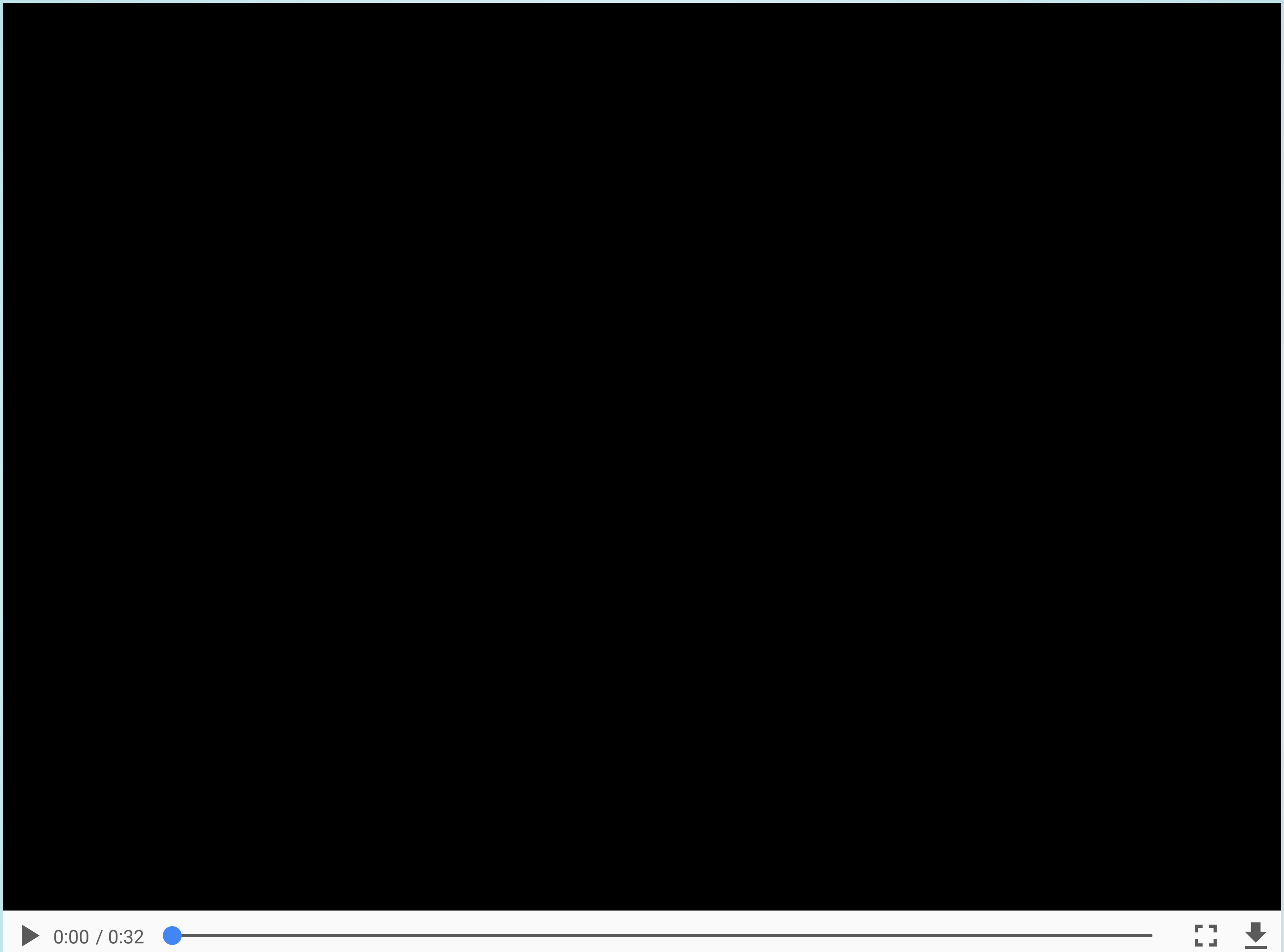
NEURONAL OSCILLATIONS



Giraud & Poeppel (2012)

NEURONAL COHERENCE



Adapted from Fries (2005)

Also see: Bastos, et al. (2015); Brunet, et al. (2015)

CONCLUSION?

“it takes the whole brain and, by extension, the whole person to participate in producing and perceiving a voice”

Sidtis & Kreiman (2011)

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