Foresight Cognitive Systems Initiative: Workshop on Speech, Language and Human Computer Interaction

Cognitive Neuroscience of Speech and Language

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- Global Foresight challenge - science funding on a 10-20 year horizon

- Specific Foresight challenge - exploit potential synergies in the interaction between computer scientists/engineers and neuroscientists/cognitive scientists in the development of complex cognitive systems

- Cognitive/psycholinguistic accounts of the functional structure of the language system.

- Neuropsychological tradition of cortical localisation of language function

- Neurobiology of relevant brain systems; primate neuroanatomy and neurophysiology

- Speech and language processing in the human brain

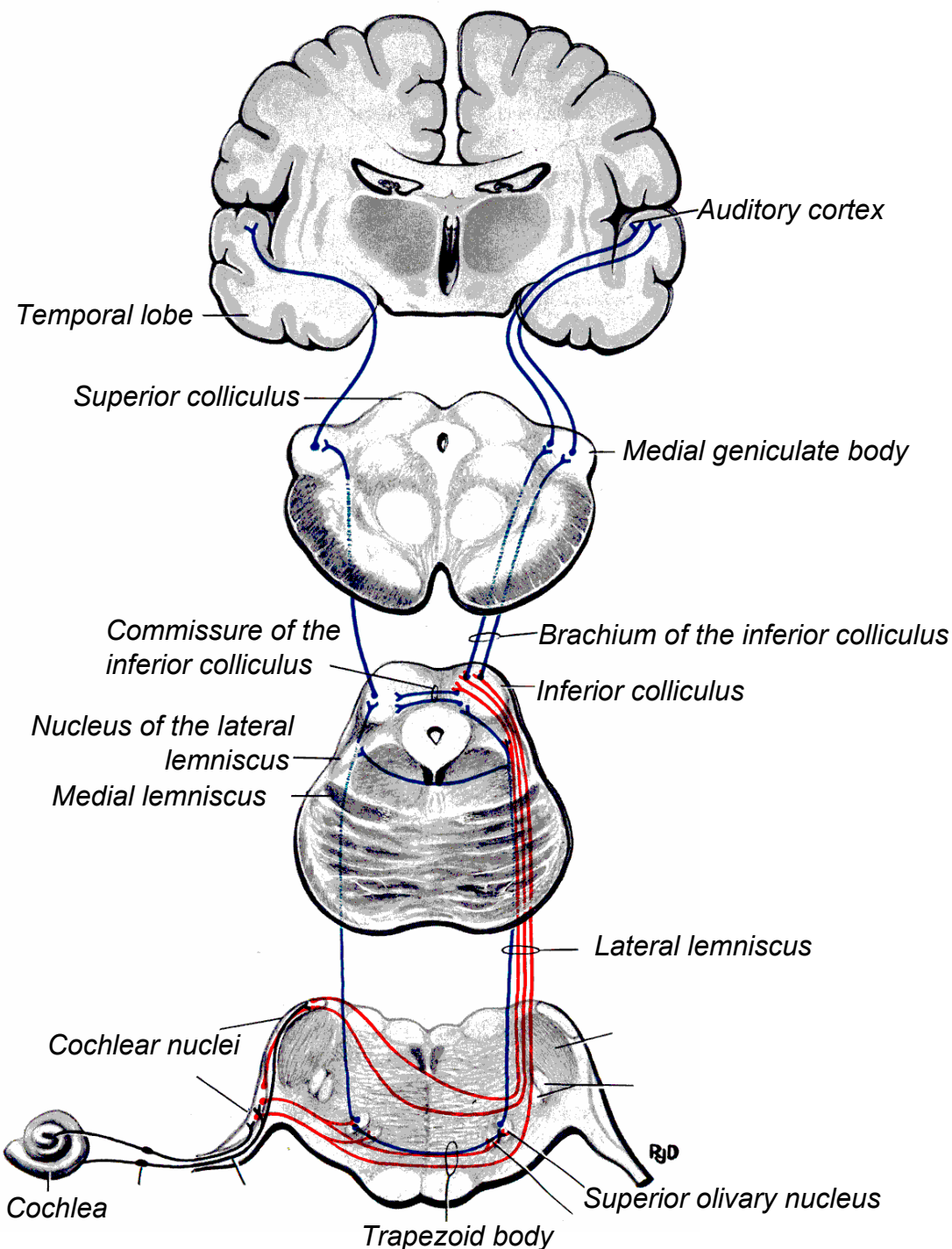- Cross-language/modality comparisons

Ascending auditory system

Many stages

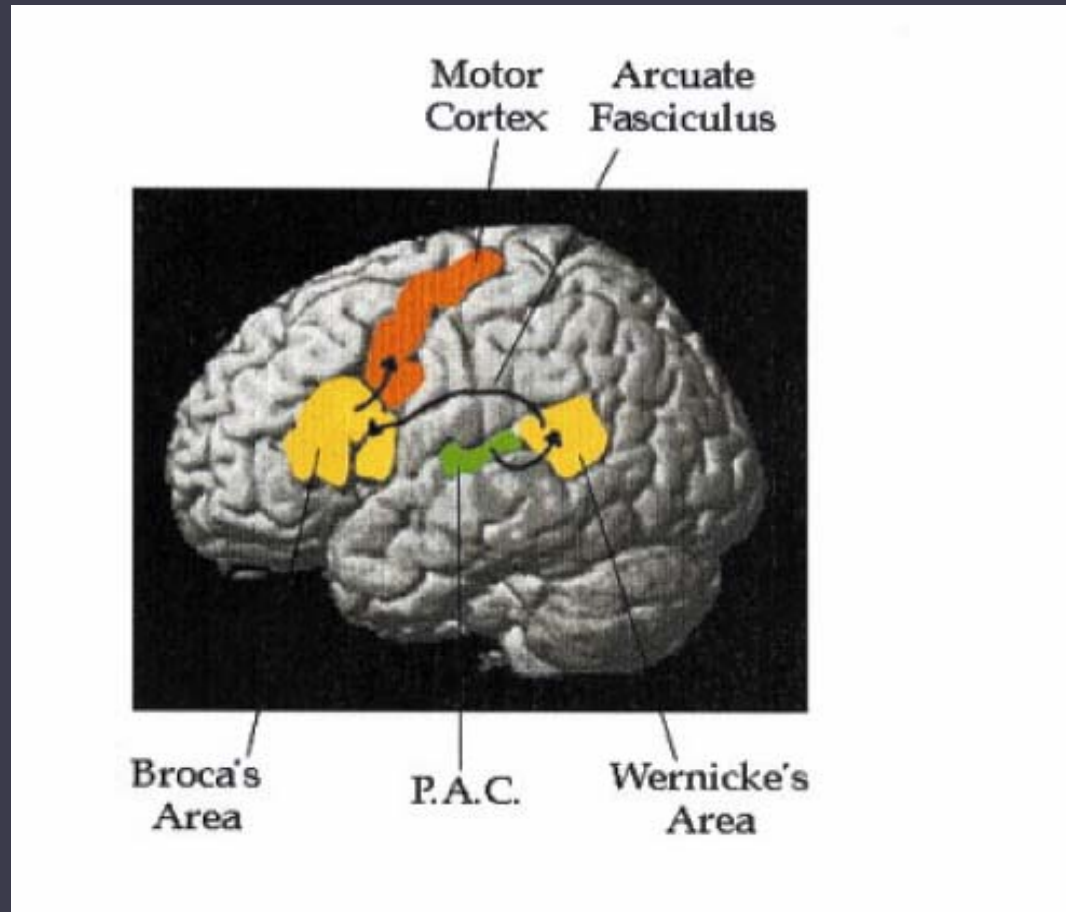Information highly processed by the time it reaches cortex

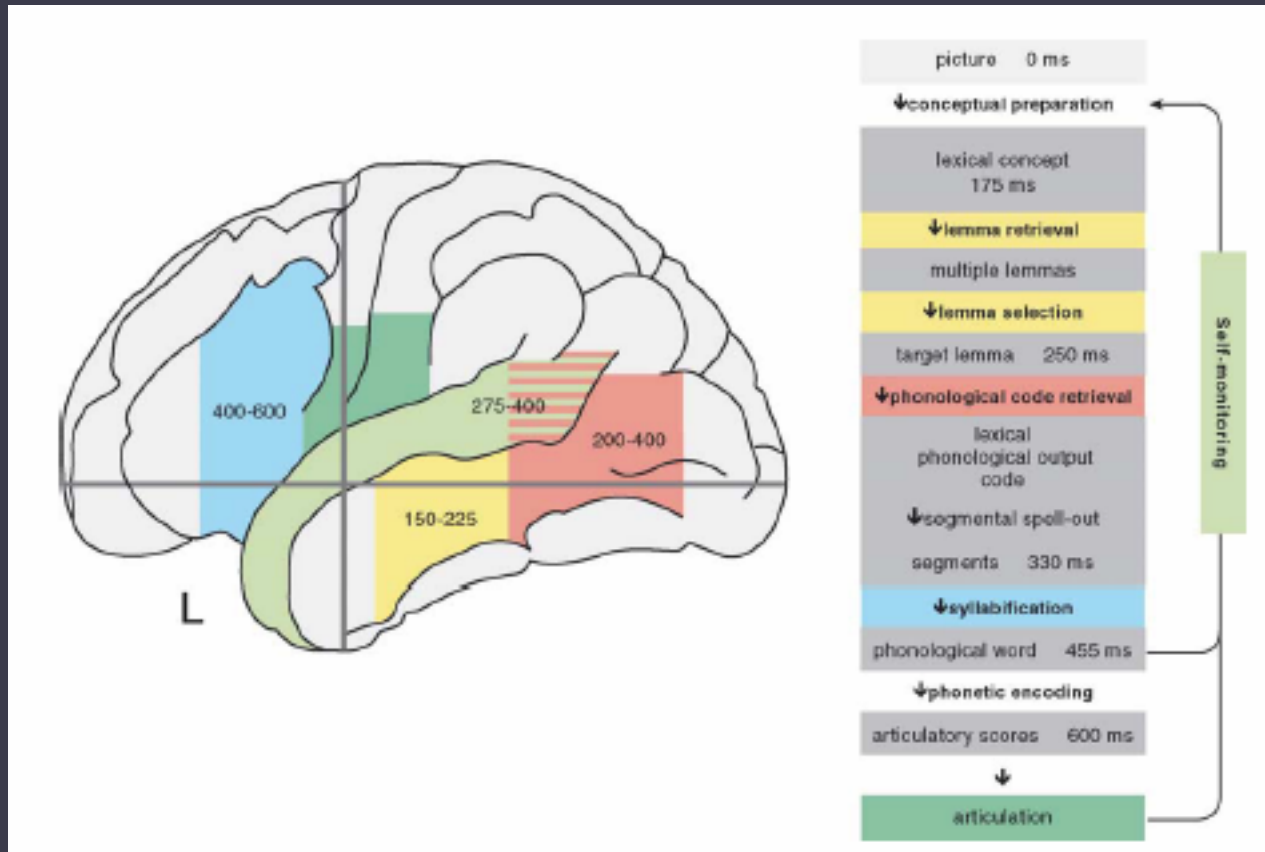Brainstem processes are sensitive to speech information

BUT:

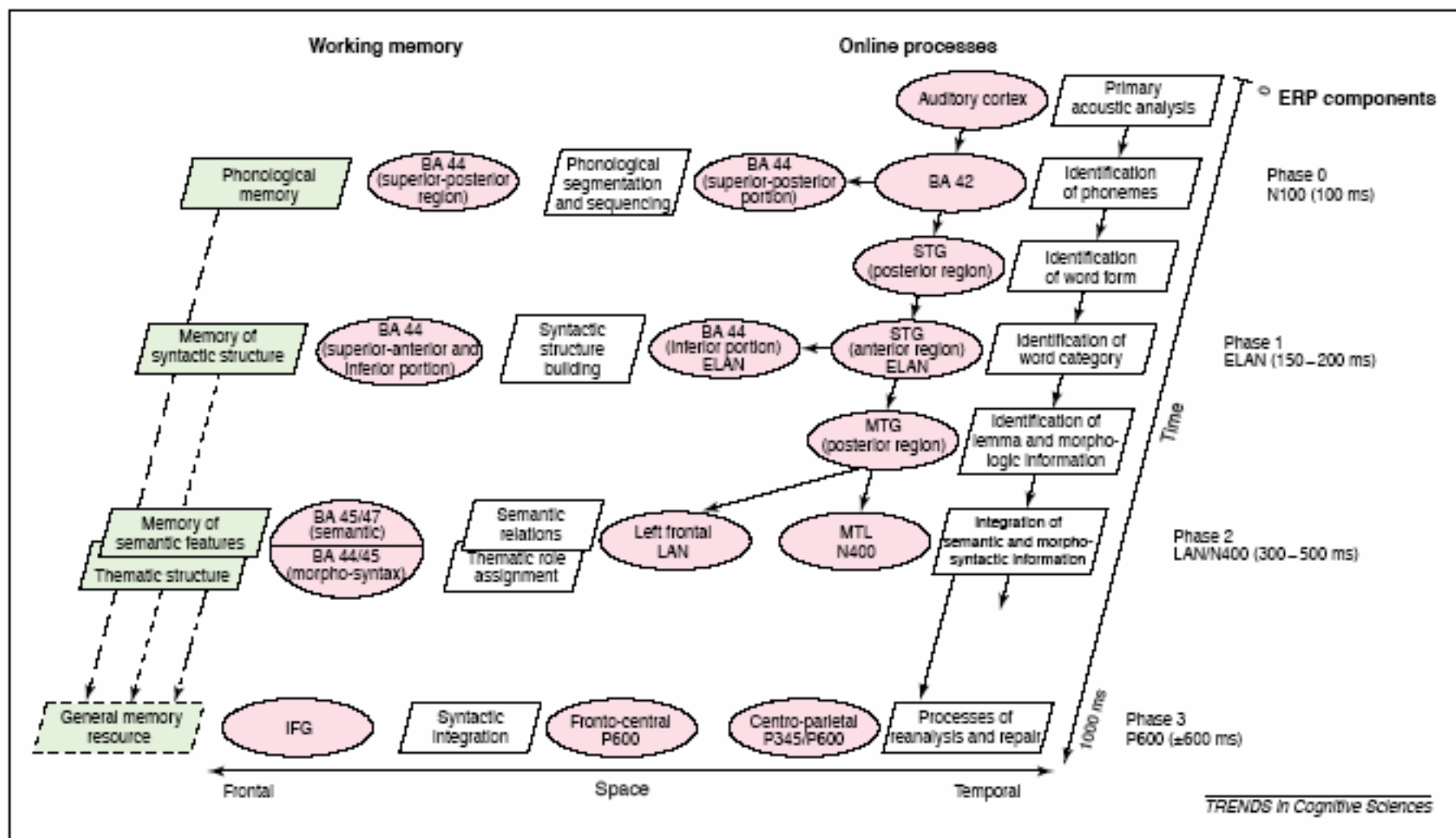Speech-specific processing (probably) unique to cortex

Neurological tradition of cortical localisation of language function: Left peri-sylvian language system

Cognitive models in the brain

Indefrey & Levelt, *Cognition* 2004
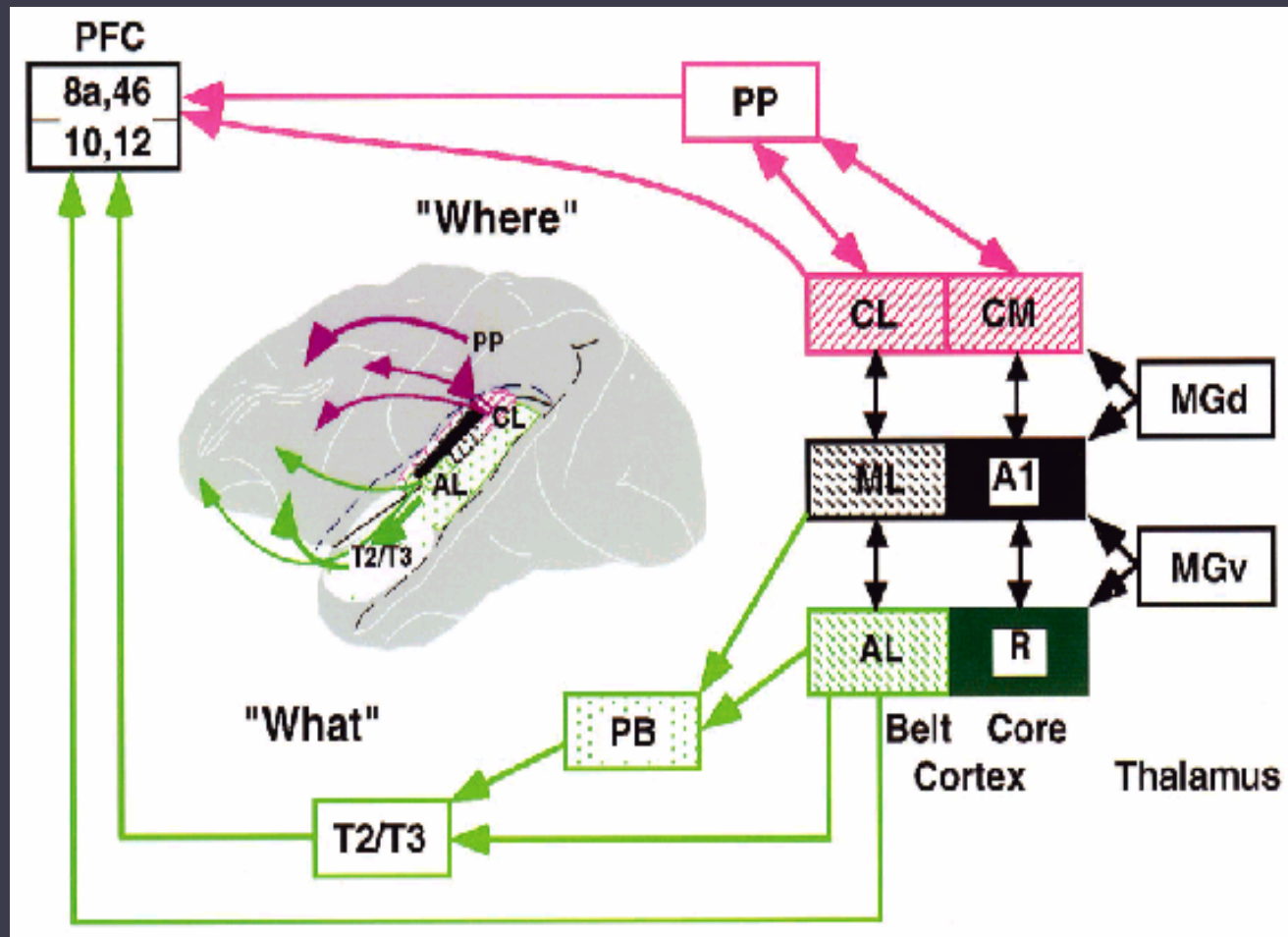
Friederici, *TICS* 2002

Implications of neurobiological models: close linkage between neuroanatomical organization and functional organization

- Multiple parallel processing streams

- Hierarchical - locally and globally?

- Complex in space and time

# Neurobiology of relevant brain systems: primate neuroanatomy and neurophysiology

(Rauschecker & Tian, *PNAS*, 2000)

- Arguably provides model of neural and functional specificity achievable for human system

- Explanation in terms of multiple hierarchical pathways

But

- Macaque brain not identical to human brain

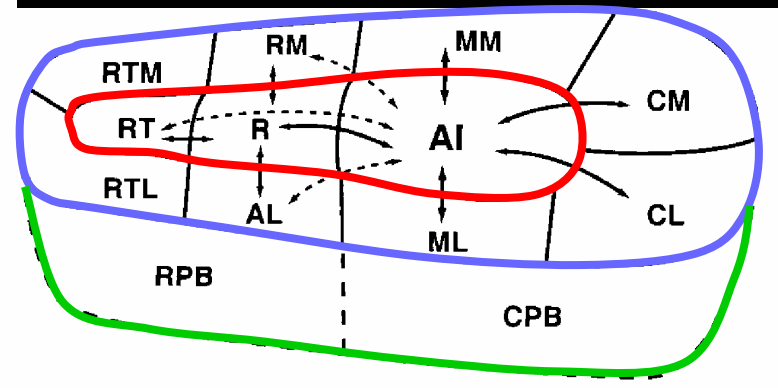- Primate auditory processing not the same as spoken linguistic communication (though see Poremba et al, *Science* 2004)
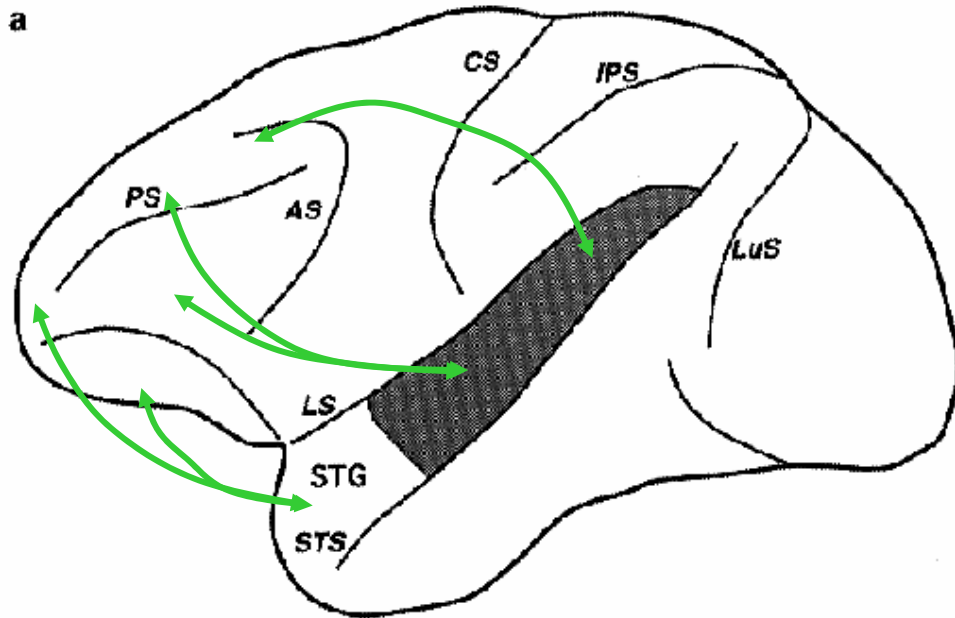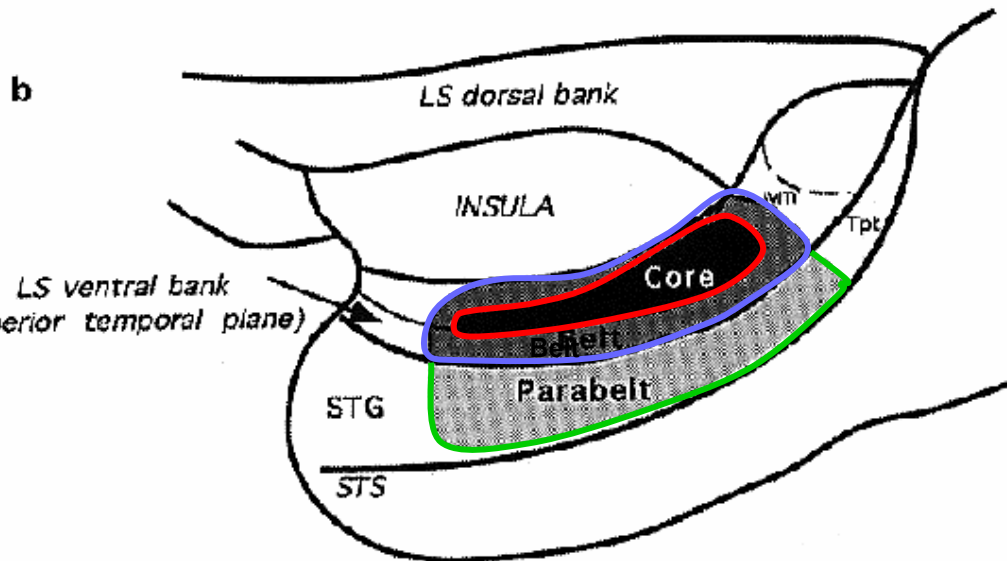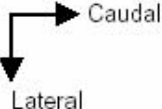
Auditory cortex in macaque monkey composed of :

Core
Belt
Parabelt

concentrically arranged
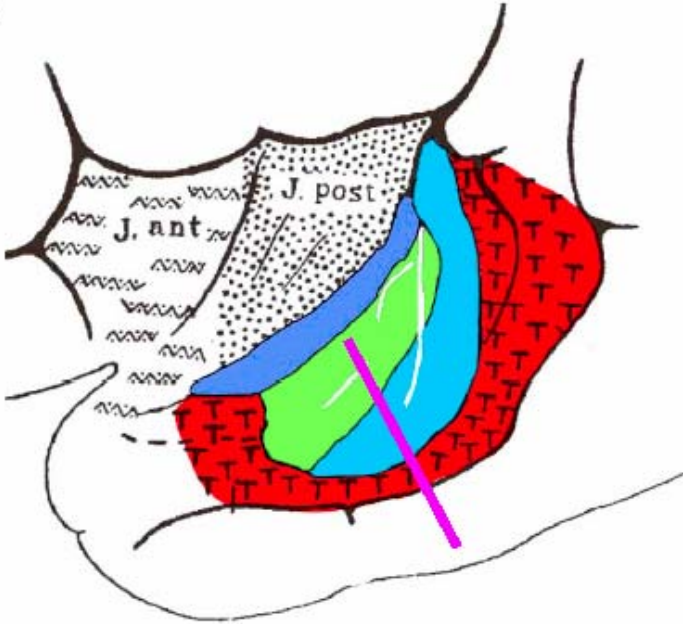
Kaas JH & Hackett TA (1998) Audiol Neurootol, 3:73-85
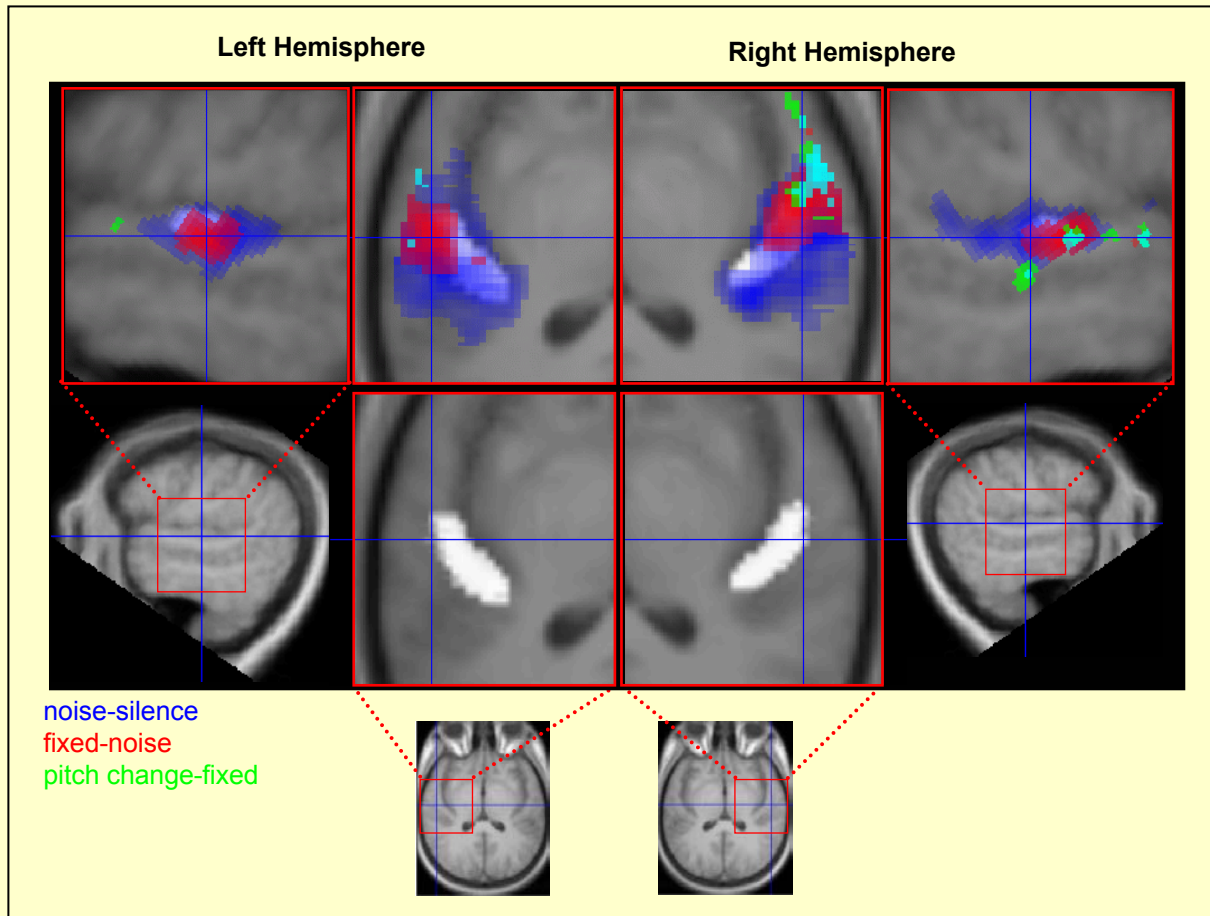
Brodmann (1909)


BA 41
BA 42
BA 22
BA 52
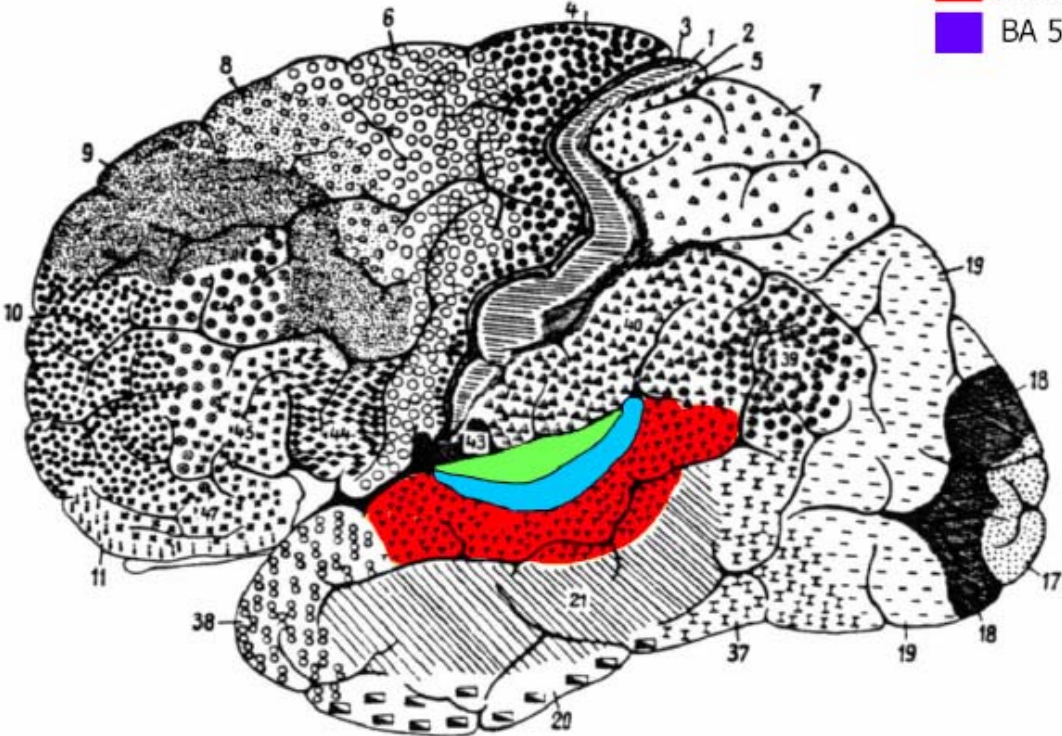
Lateral view

View of the supratemporal plane

Homologues in human brain

Hierarchical organisation of processes in human primary auditory cortex (belt, parabelt)

noise-silence
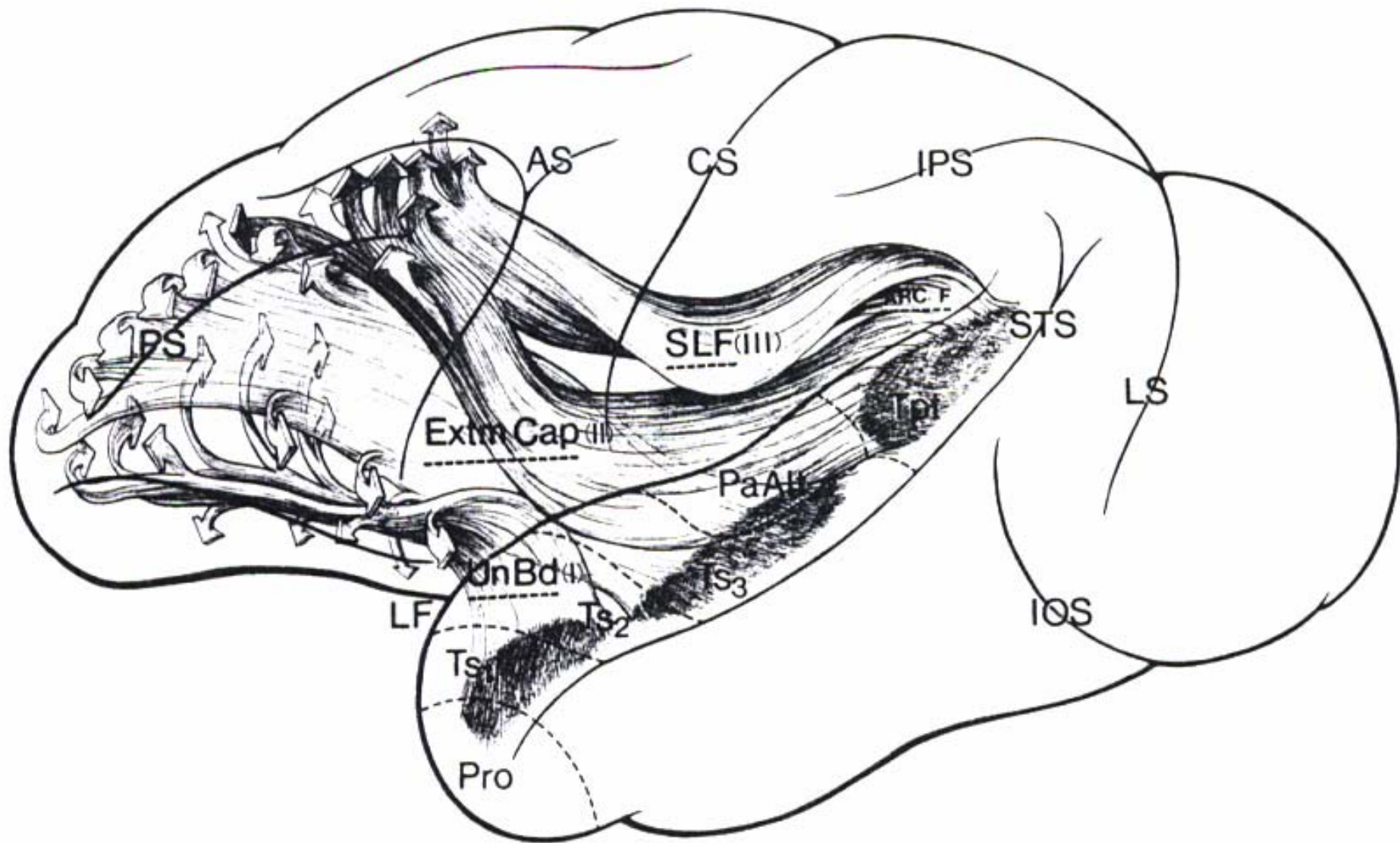fixed-noise
pitch change-fixed

(from Patterson, Uppenkamp, Johnsrude & Griffiths, *Neuron*, 2002)

Possible processing streams: Belt and parabelt connections with prefrontal cortex in the macaque
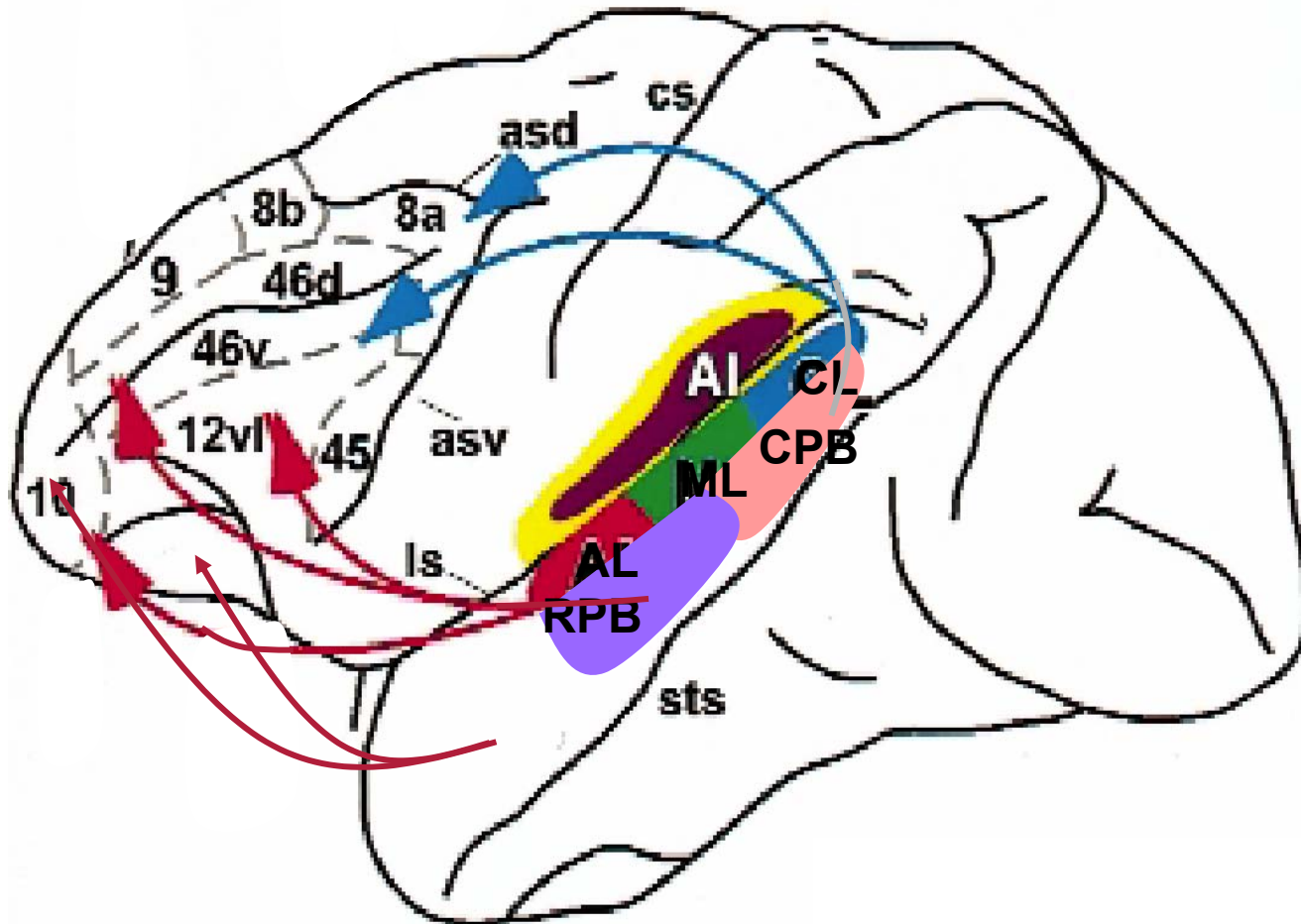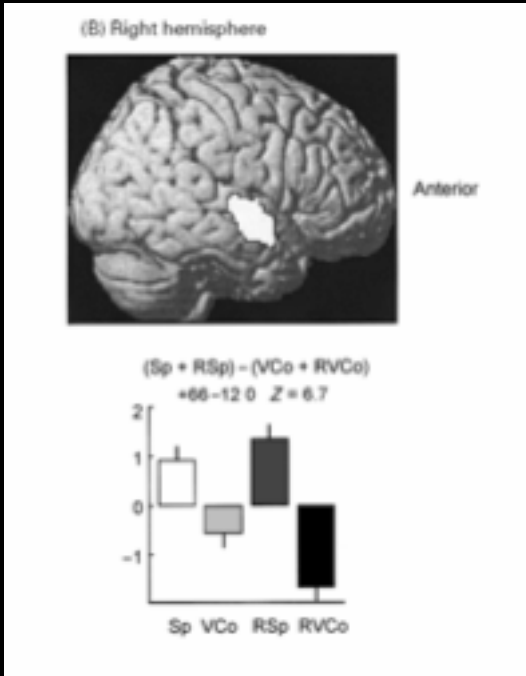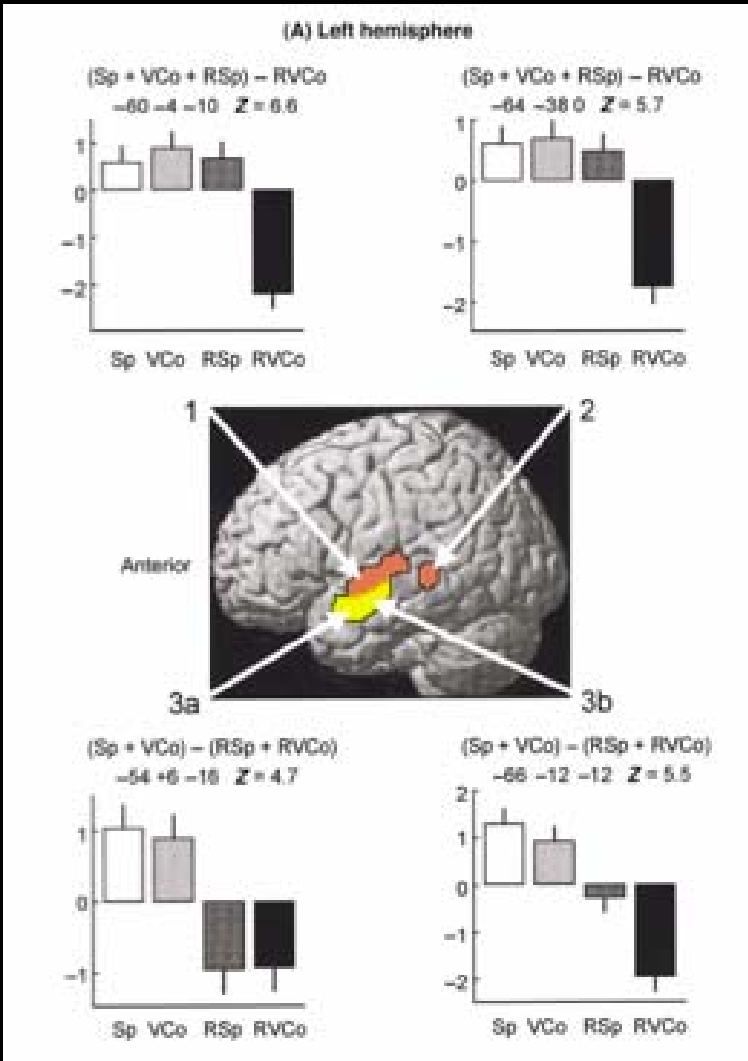
Petrides M & Pandya, DN (1988).
J Comparative Neurology, 273, 52-66
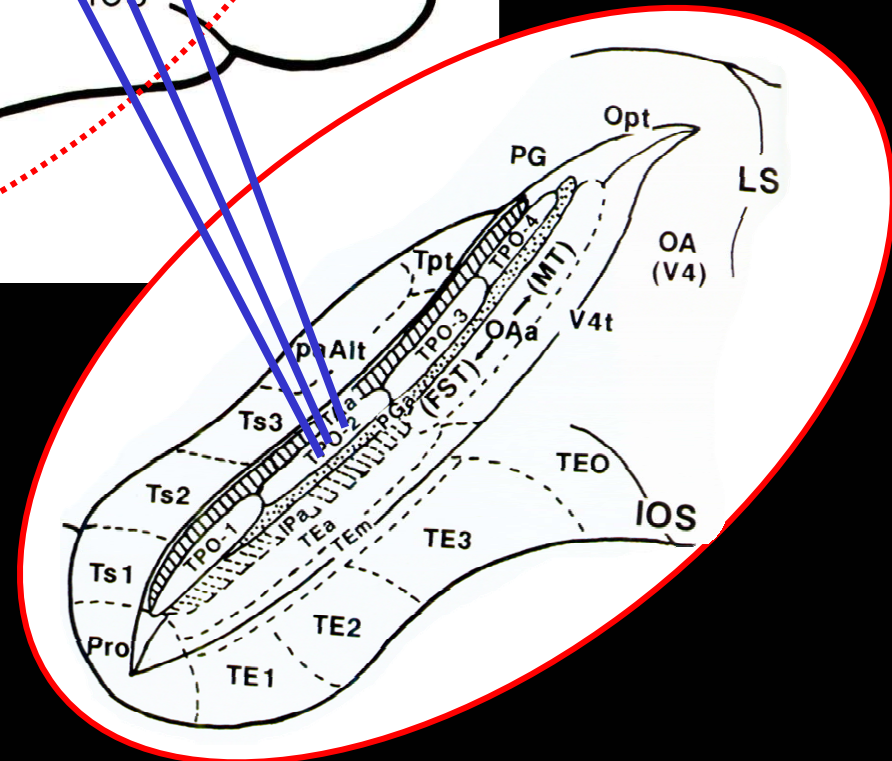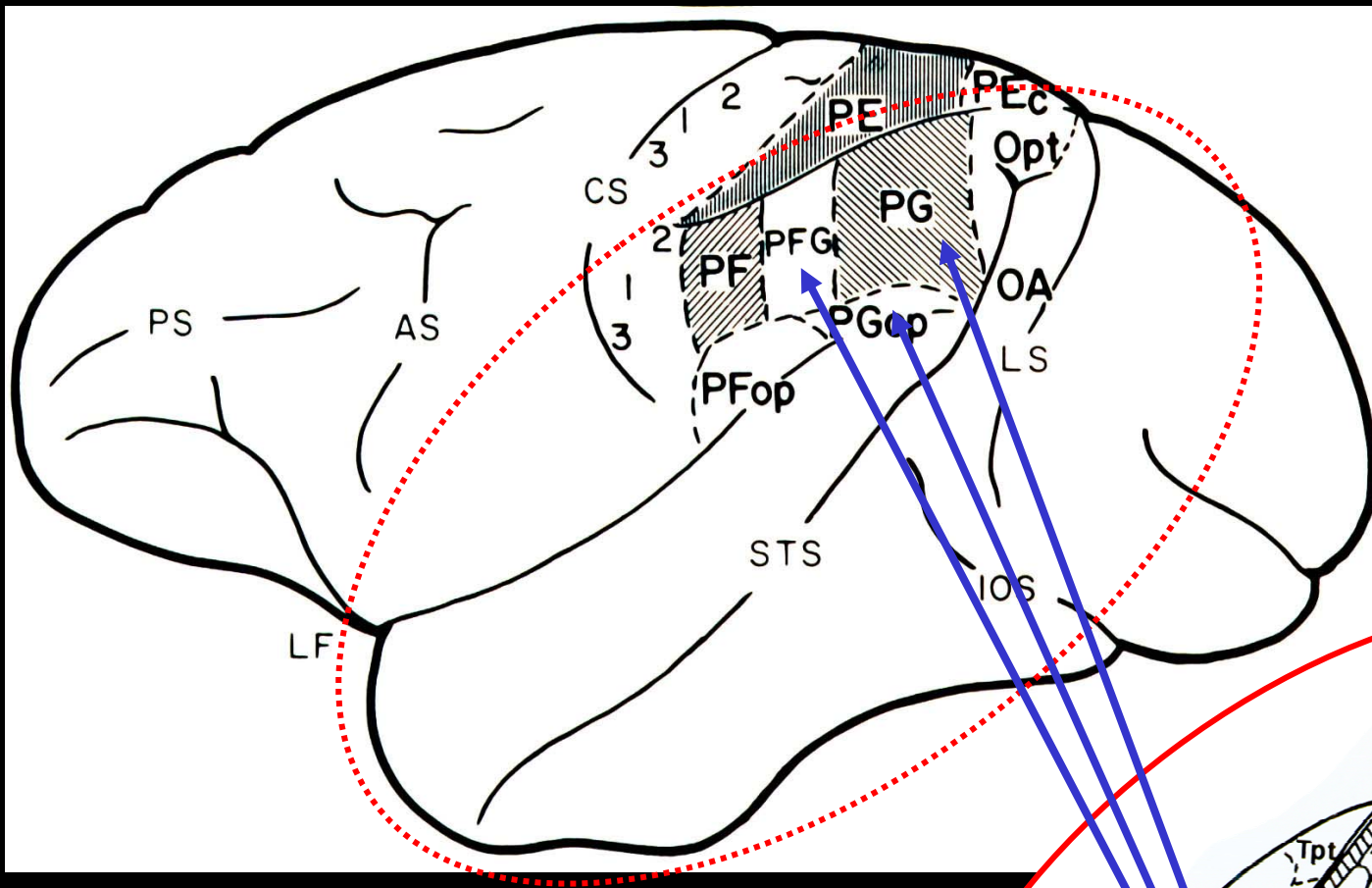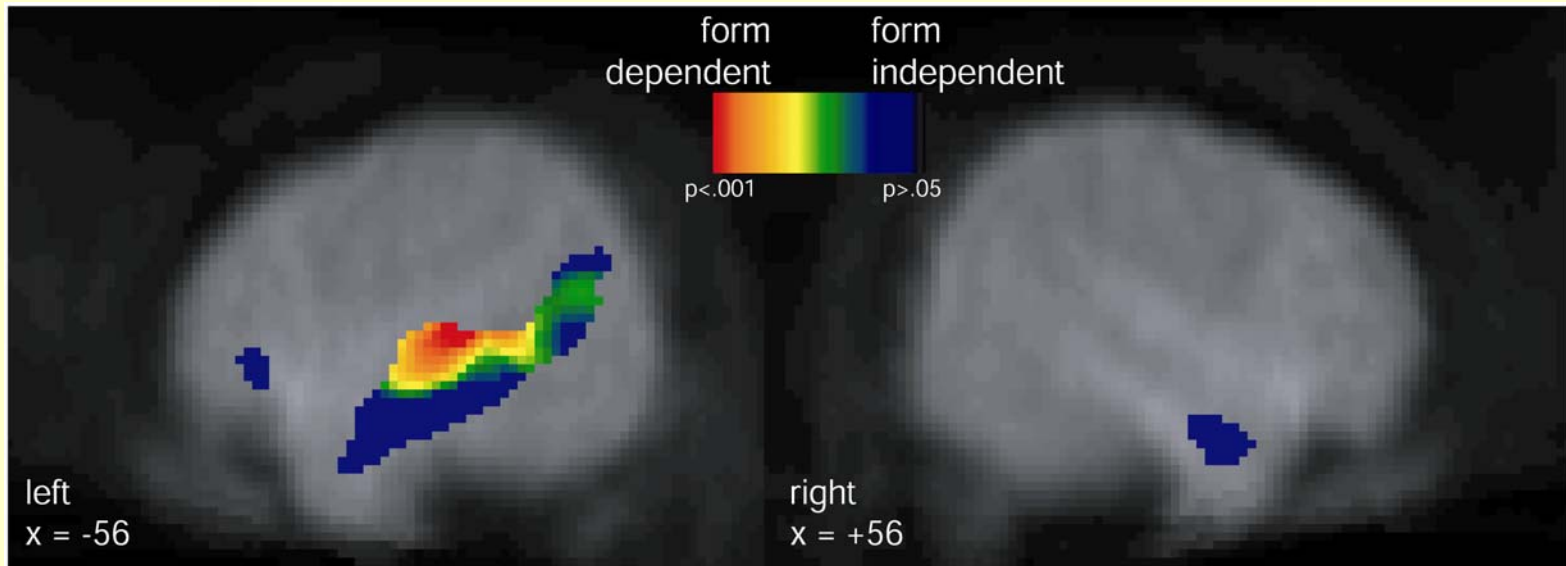
Parietal: Pandya & Seltzer (1982)
                J Comp Neurol, 204: 196-210

STS: Seltzer & Pandya (1991)
                J Comp Neurol 312: 625-40.

Functional evidence for hierarchical organization of processing streams

Hierarchical organization of processing streams

Activation as a function of intelligibility for auditorily presented sentences (Davis & Johnsrude, *J. Neurosci*, 2003). Colour scale plots intelligibility-responsive regions which showed a reliable difference between different forms of distortion (orange to red) or no reliable difference between distortions (green to blue).
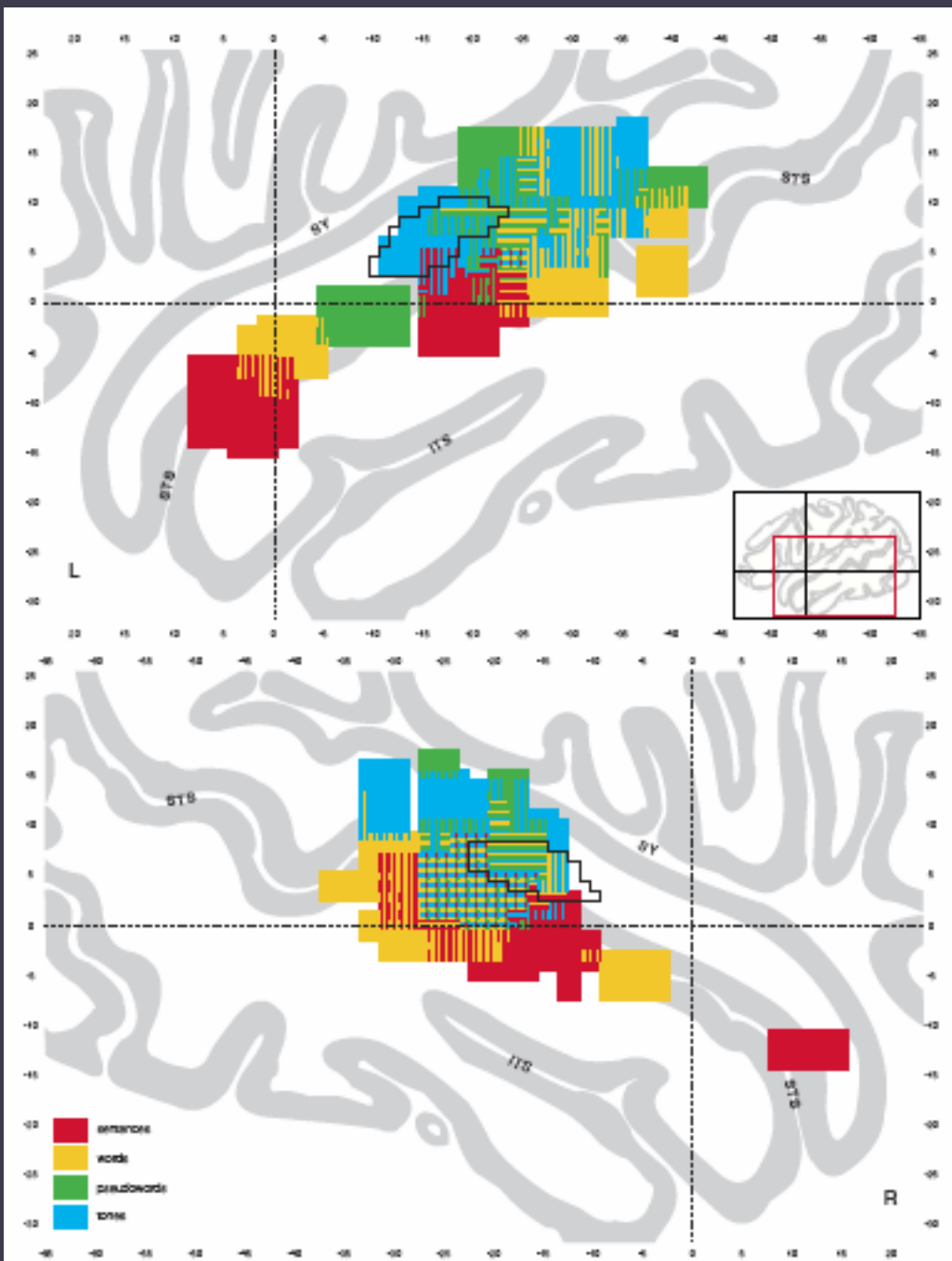
Bilateral hierarchy emerging from meta-analyses of neuro-imaging research on speech and language processing

Indefrey & Cutler, 2003

Electrocortical localisation using cortical stimulation (functional lesions)
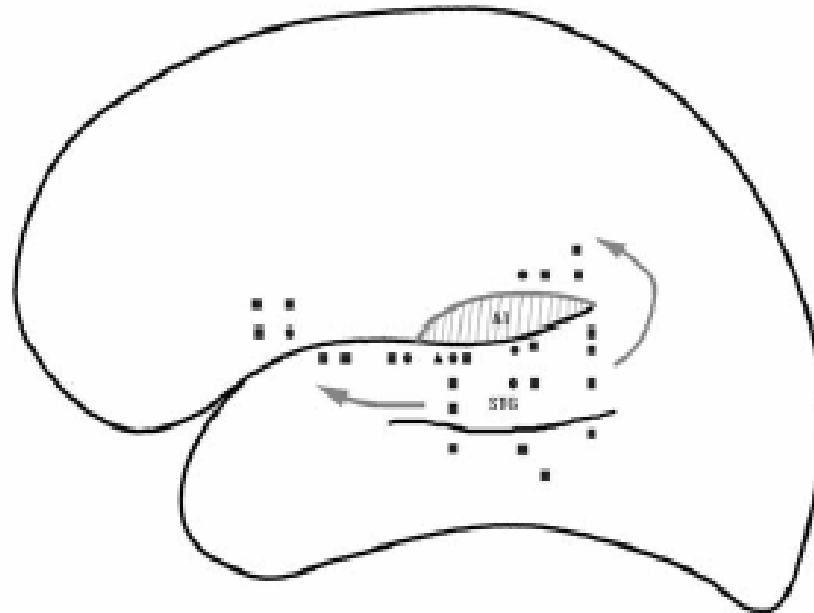

Fig. 4. Schematic representing most common locations of phonetic discrimination (▲), phoneme identification (●), and auditory comprehension (■) deficits induced during electrocortical mapping. Arrows delineate anterior and posterior directions of auditory information transmission in the temporal lobe.

Boatman, *Cognition* 2004

Transmission latencies: closely interconnected perisylvian networks

MFG

10 ms

6 ms

IFG

2 ms
PLST

10 ms

MTG

ITG
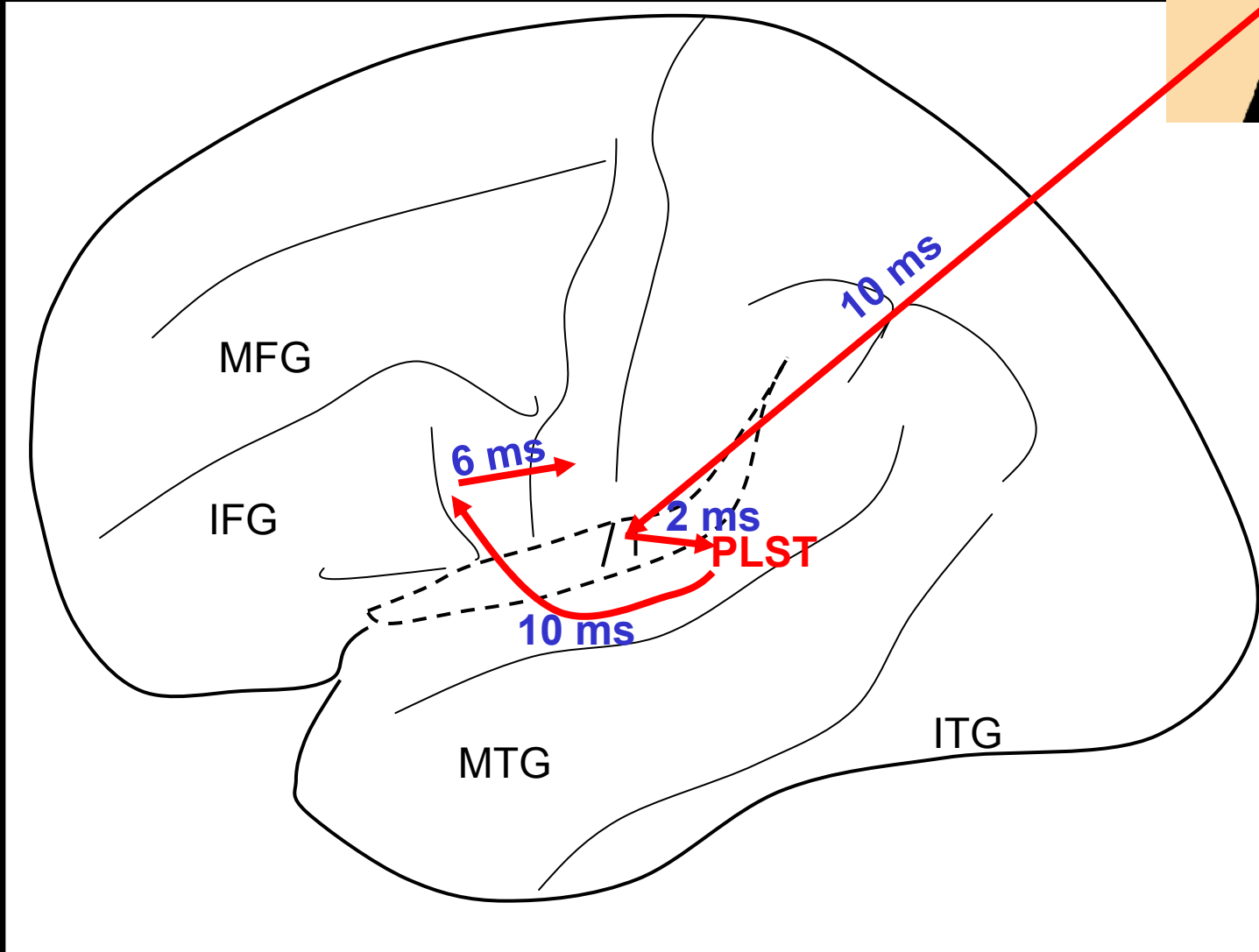
Brugge et al (2003) J Neurophysiol., 90 3750-63.
Greenlee et al (in press) J Neurophysiol.
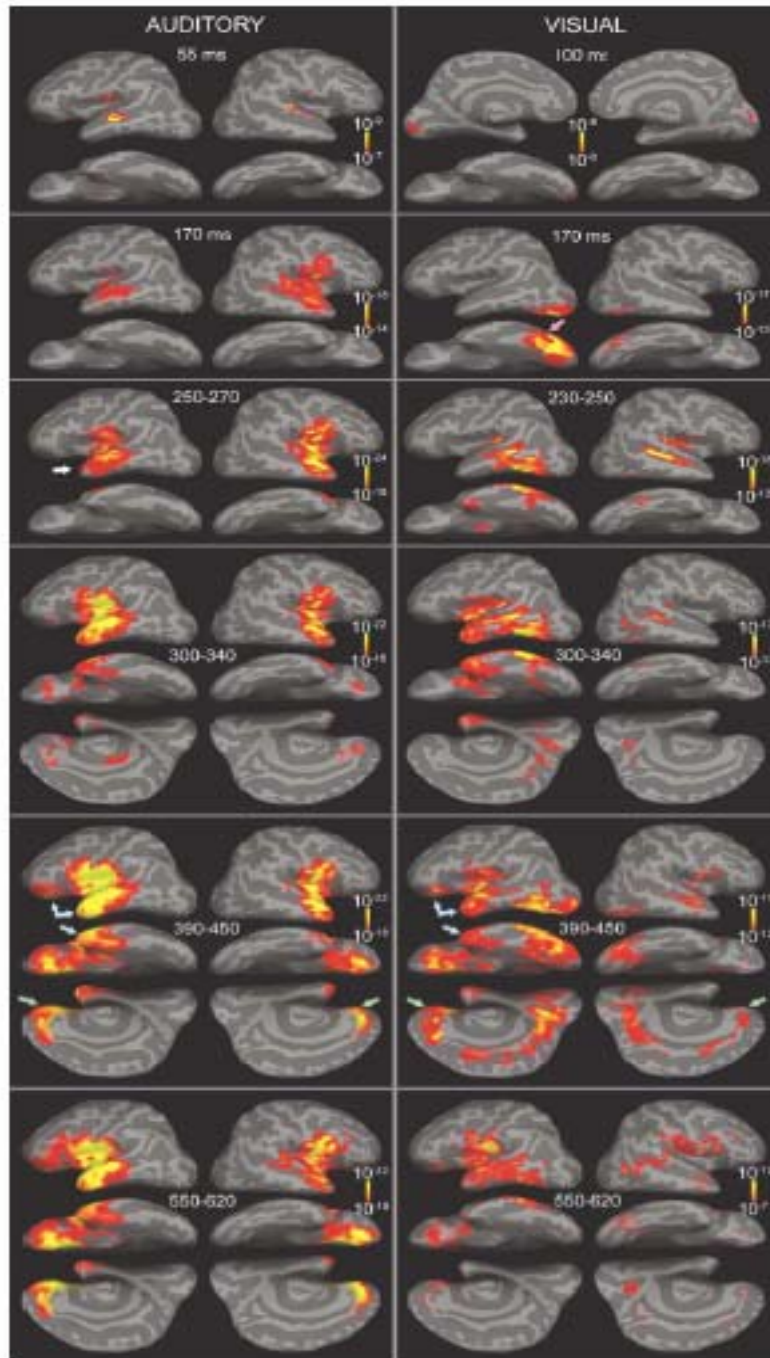
Dynamic spatio-temporal activation patterns in MEG

Marinkovic et al *Neuron* 2003

Core peri-sylvian language system

- Multiple processing streams

- Locally (globally?) hierarchical

- Bilateral

- Complex in space and time

Challenges

- Multi-modal imaging: capturing spatio-temporal dynamics

- In vivo neuroanatomy (tractography)

- Neuro-biologically realistic computational modelling

- Learning and plasticity

And many others….