The Brain

Informatics 1 Cognitive Science

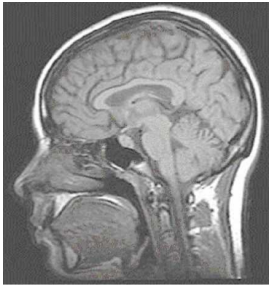
Matthias Hennig

School of Informatics
University of Edinburgh
mhennig@inf.ed.ac.uk

Today's topics

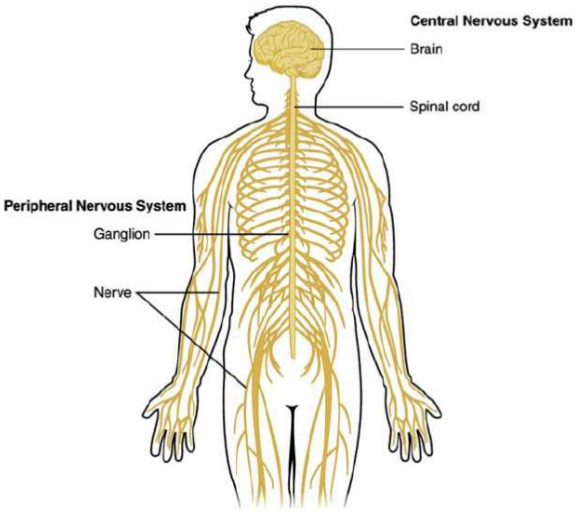
- Basic brain anatomy
- The cortex as the site of higher cognitive function
- Anatomy and functional specialisation in the brain

The Human Brain

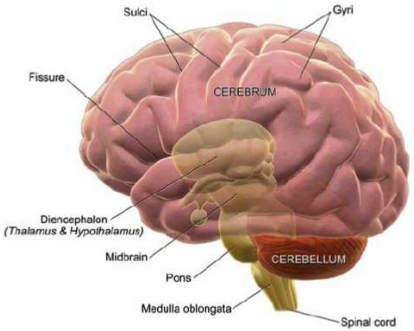


- Around $90 \cdot 10^9$ neurons, 10^{14} connections between them.
  (African elephant: $300 \cdot 10^9$ neurons)
- Connected to the rest of the body through brainstem / spinal cord.
- Typical weight is 1.2-1.5kg (about 2% of body mass), but it consumes 20% of the energy we expend.
- Your brain runs on about 20W.

The Central and Peripheral Nervous System

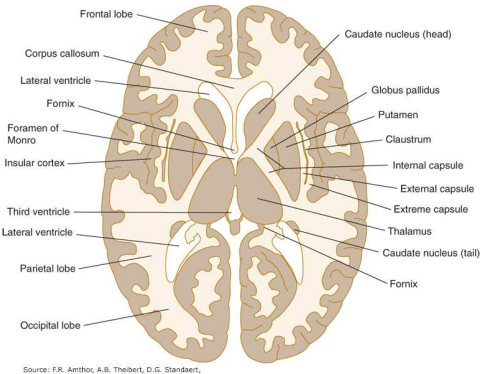


Anatomical subdivision of the Brain



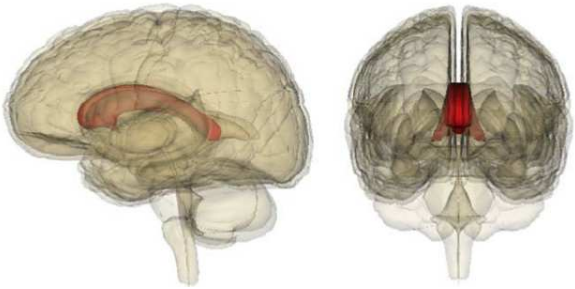
- The cortex is the outer layer of the brain and highly convoluted $\rightarrow$ large surface area
- The thalamus interconnects different areas of the cortex
- Beneath it we find the midbrain, cerebellum and other structures

Grey and White Matter



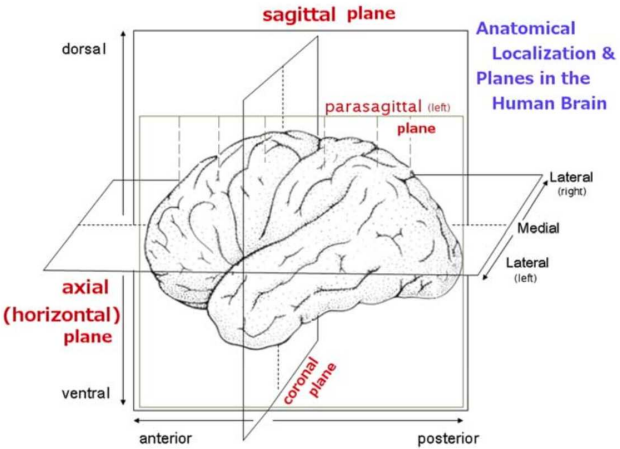
- Grey (pink when living) matter: contains nerve cells
- White matter: contains connections between cells

The two Hemispheres



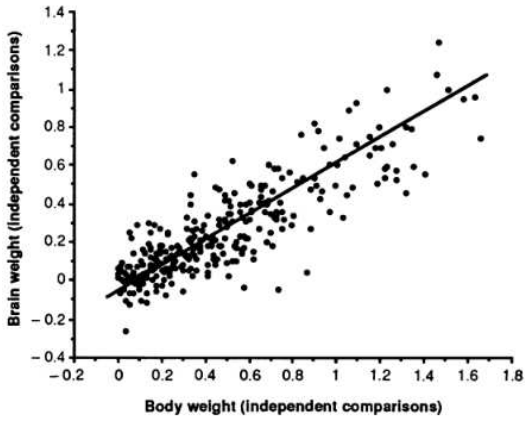
- Left hemisphere: analytical tasks, usually speech + language (Broca's / Wernicke's areas)
- Right hemisphere: retrieval/maintenance of information, e.g. map reading
- The hemispheres are connected by the corpus callosum
- These connections are not essential for some common brain functions, but required for many tasks and learning.

Anatomical references



- superior: above - inferior: below
- proximal: close - distal: away
- superficial: near the surface - deep: inside
- temporal: near the temporal bone
- parietal: near the parietal bone
- occipital: near the occipital bone

Bigger bodies, bigger brains

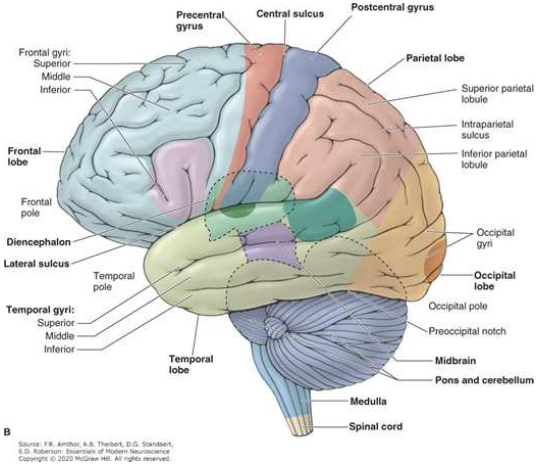


Harvey, P. H., & Krebs, J. R. (1990). Comparing brains. Science, 249(4965), 140-146.

How to assess brain function?

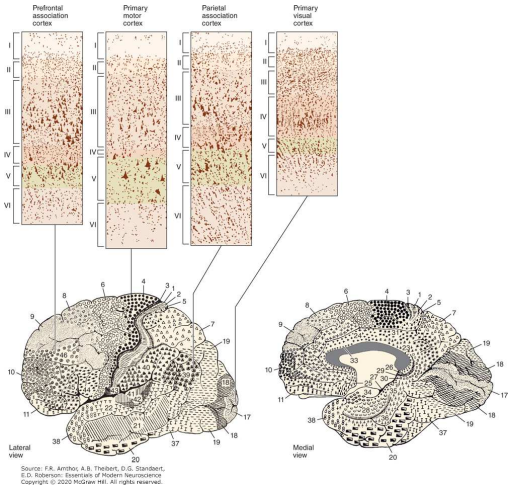
- Historically, the autopsy of patients with neurological deficits has given insights into the importance of some brain regions.
- This dates back to the middle ages, when Islamic medicine discovered the association between neurological symptoms and brain injury.
- The more detailed study of anatomy (Camillo Golgi and Ramón y Cajal, 1890s) and discovery of electrical activity in the brain (Luigi Galvani, Lucia Galeazzi Galvani and Giovanni Aldini) started modern neuroscience.
- Today non-invasive methods such as PET/MRI scanners are used for anatomical studies, and fMRI scanners or EEG report activity.

The Cortex: anatomical landmarks



4 main lobes: frontal, temporal, parietal, occipital, with further anatomical subdivisions

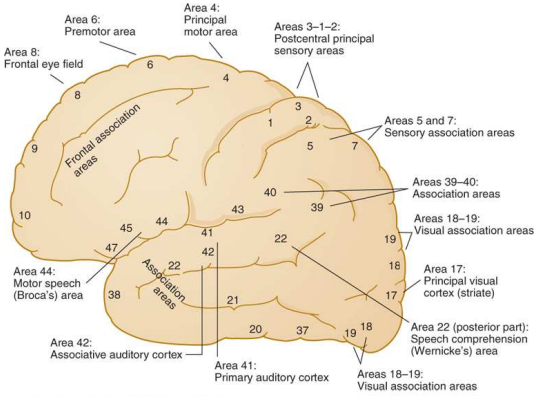
Cytoarchitecture of the Cortex



- Between 2 and 4 mm thick and overlying white matter.
- A distinct 6-layer organisation.
- Detailed organisation differs between areas.
- This overall architecture is well conserved across mammals.
- This suggests the cortex may implement a general purpose organisation for cognition and action.

Brodmann's areas

Cytoarchitecture reflects the functional specialisation of the Cortex



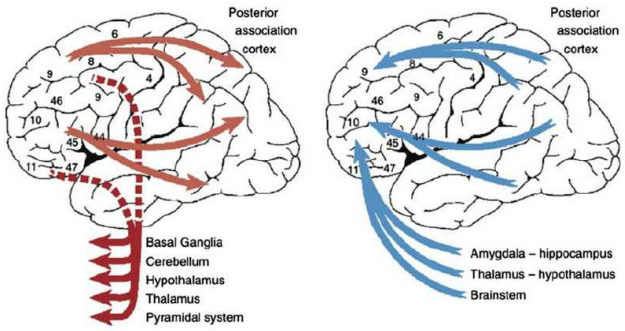
Source: F.R. Amthor, A.B. Theibert, D.G. Standaert, E.D. Roberson: Essentials of Modern Neuroscience

The Allen Brain Atlas

An online resource to the brain.

http://atlas.brain-map.org/

The Frontal Cortex



- Highly connected to the rest of the brain.
- Required for many executive functions: guide and plan behaviour, switch behaviours if required.
- Social cognition and perhaps consciousness.

Consequences of pre-frontal cortex damage

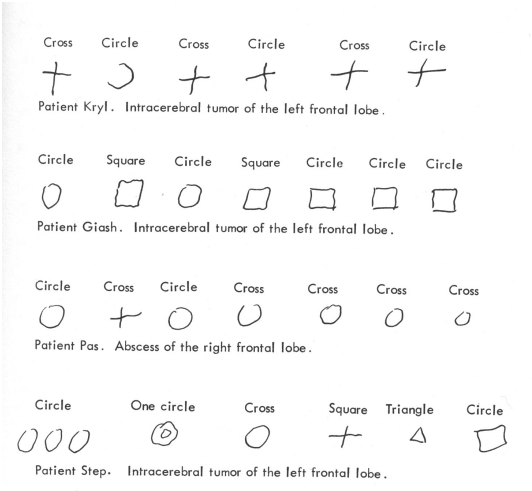
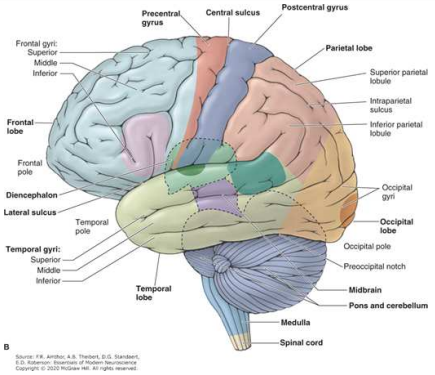


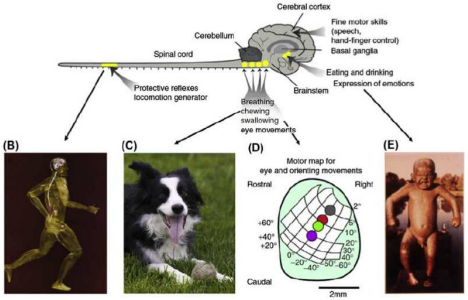
FIGURE 66 Disturbance of the performance of single tasks as a result of pathological inertia of action in patients with extensive lesions of the frontal lobes.

The Sensory Cortices



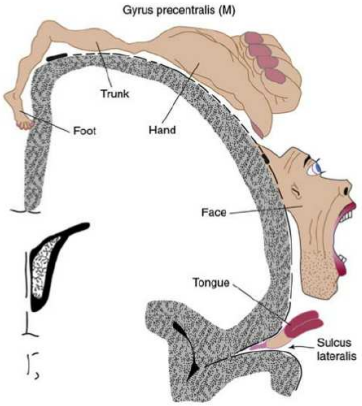
- Occipital: vision
- Temporal: Auditory and olfaction
- Parietal: somatosensory cortex - touch, temperature, pain, proprioceptive information and some executive function

The Motor System



- Includes the spinal cord, the cerebellum, brainstem and motor cortices.
- Spinal cord: movement initiation
- Brainstem: basic and largely automatic movements (breathing, swallowing, eye movements)
- Motor cortex: more complex movements, expression of emotion

The Motor Homunculus

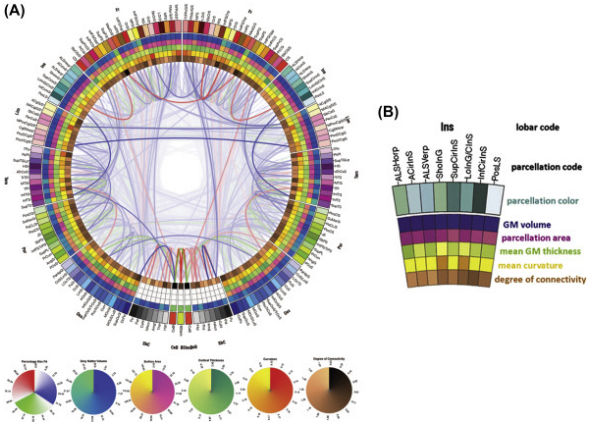


The representation of the body is topographically organised. Yet, the amount of cortex dedicated to different body parts differs significantly.

Other brain areas

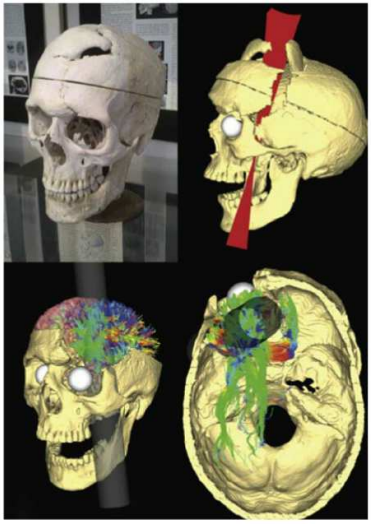
- Cerebellum (small brain): timing, in particular motor function
  - damage results in loss of precise motor function:
    `https://www.youtube.com/watch?v=Gn3AcxSn-Dc`
- Hippocampus (seahorse): episodic memory, "buffer" for long term storage
  - damage prevents new memories from being stored, leads to antero-grade amnesia
  - A famous case is Patient HM:
    `https://www.youtube.com/watch?v=EDPiH9xfMwU`
    `https://www.youtube.com/watch?v=D7Ma7ixtDdM`

Brain Connectivity



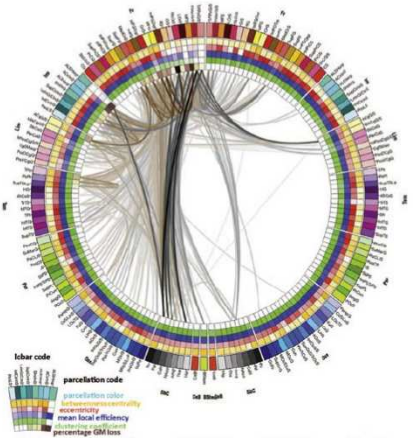
The circular Connectogram, showing all brain areas in both hemispheres. Lobes: frontal lobe (fr), insular cortex (Ins), limbic lobe (Lim), temporal lobe (Tem), parietal lobe (Par), occipital lobe (Occ), subcortical structures (SbC), and cerebellum. The brainstem (BStem) is at the bottom.

Phineas Gage



- A 25-year old railroad construction supervisor.
- In 1848, an accident caused a tamping iron to shoot through his skull and brain in the left frontal area.
- The tamping iron landed point-first some 80 feet (25 m) away, “smeared with blood and brain”.
- Physician’s report: When I drove up he said, “Doctor, here is business enough for you.”
- Initially personality changes were reported, but he lived on for 12 years and recovered remarkably well.

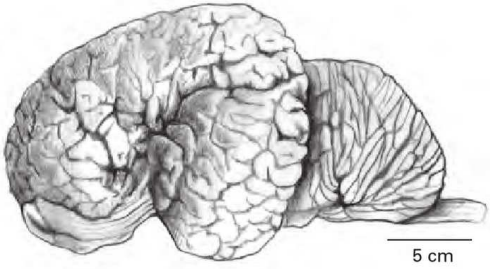
Phineas Gage's Brain Connectivity



Gage's connectogram was severely affected, but the successful recovery suggests even the adult brain has remarkable plasticity and the ability to compensate for injury.

Are larger brains better brains?

human brain

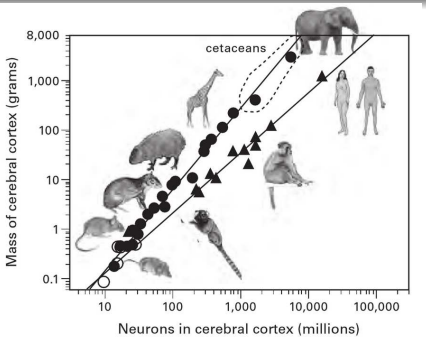


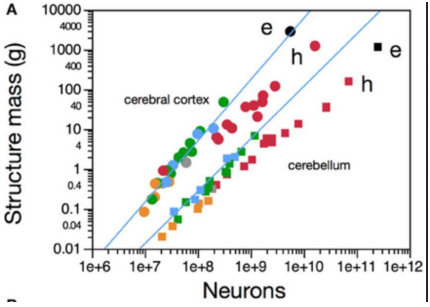
elephant brain

The elephant has 257 billion neurons, while we only have 86 billion!?

Herculano-Houzel, Suzana. The Human Advantage : A New Understanding of How Our Brain Became Remarkable, MIT Press, 2016.

Do larger cortices make better brains?





- Elephant cortex: 5.6 billion neurons
- Human cortex: 16 billion (9 billion in the gorilla)
- A much higher neuron density in the human cortex
- The elephant cerebellum has a disproportionately high neuron number

Summary so far

- The brain has anatomically distinct parts, and many of these parts are further subdivided anatomically.
- This anatomical division reflects some degree of functional specialisation.
- Brain regions are highly interconnected (white matter) - so no region would work just on its own.
- Higher cognitive abilities depend critically on the cortex and the networks it forms.