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Module:	Techniques & Physics
Lecture:	Functional Imaging Basics 2 Neurovascular techniques
Description:	Physiological and physical basis of Positron Emission Tomography and functional Magnetic Resonance Imaging
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Objectives:

- Know the physiological mechanisms recorded
- Understand the basis of PET and fMRI
- Understand the strength and weaknesses of these techniques

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Prerequisites:

- No prerequisite

The Brain Metabolism

We can exploit a feature of neuronal metabolism to image the brain in action:

- The brain weight ~1.4Kg ie only ~2% of the total body weight.
- The brain has large metabolic need:
- it uses ~20% of the whole blood oxygen
- It uses ~750ml of blood every minute, extracting 900mg of glucose from it (ie ~10% of the ~1.2mg/ml)

- This extraordinary consumption of oxygen and glucose is explained by the absence of energetic reserve in the brain which ‘burns’ from 30 to 50 micro-mol of ATP every min per gram of tissue (Attwell and Laughtin, 2001).

Positron Emission Tomography (PET)

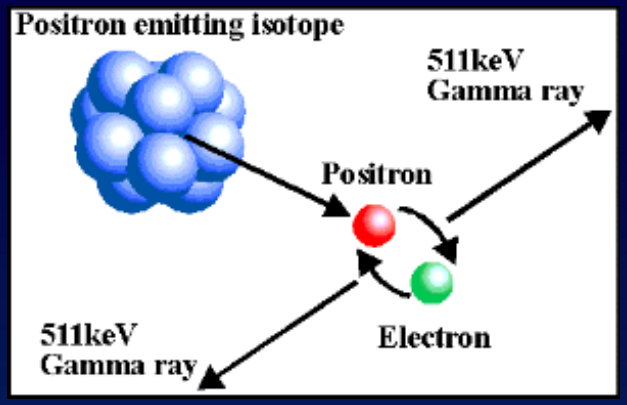
- Ketty & Sokoloff (USA, 1960, animals)
- Ingvar & Lassen (Scandinavia, 1963, humans)

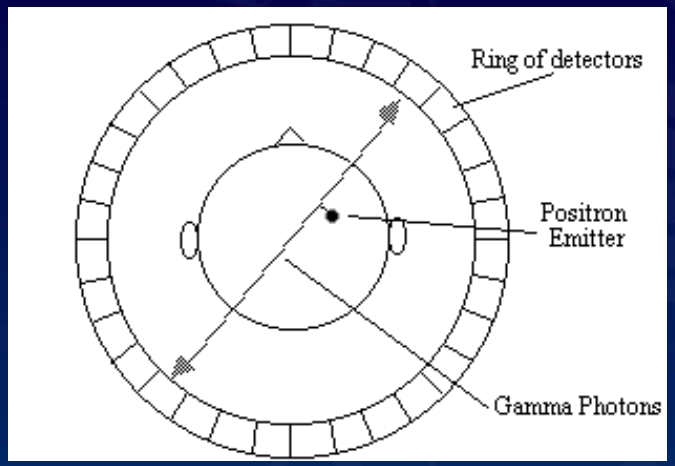
Typical ‘Brain Activation’ PET Protocol:

- Subjects injected with **radioactively-labelled water** (made with 15O)
- This radioactive water accumulates within the brain in **direct**
- **Proportional** with local blood flow
- The **greater** the blood flow (due to increase local neuronal activity), the **greater** the radioactive count-rate in specific brain areas
- H2O15 decays rapidly with a half life of 2 min and disappear to background after roughly ten minutes. This means that while we minimize subject exposure, the quality of images is degraded (spatial resolution is ~10mm)
- Water is the best tracer for functional experiments as it allows several observations (typically blocks of activations) to be made in a shorter time period

Positron Emission Tomography (PET)

- PET with O-15 is the ‘gold standard’ for brain activation studies
- Emits positrons which collide with electrons and emit gamma rays at 90° to collision

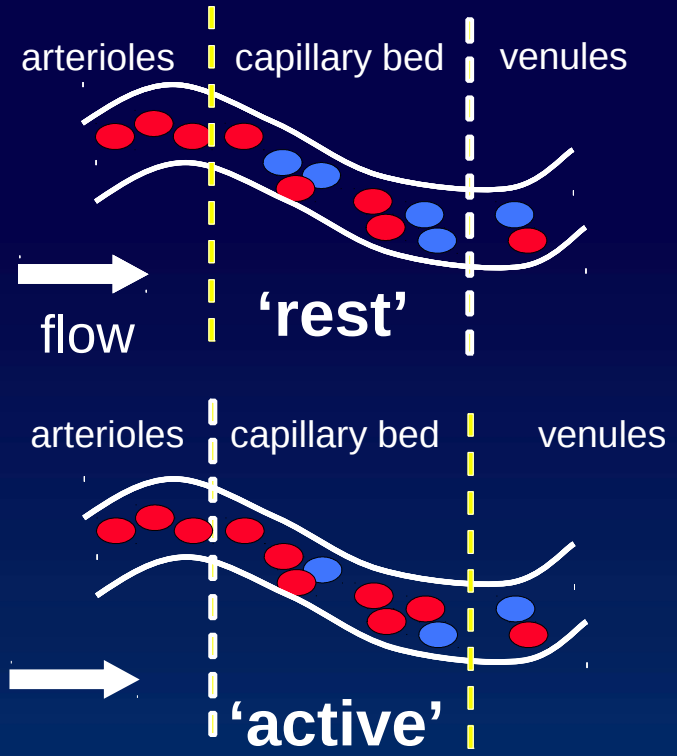




- Simultaneous gamma ray emission is picked up by ring of ***coincidence detectors*** arranged around subject’s head in scanner.

Functional MRI

Contrast Mechanisms

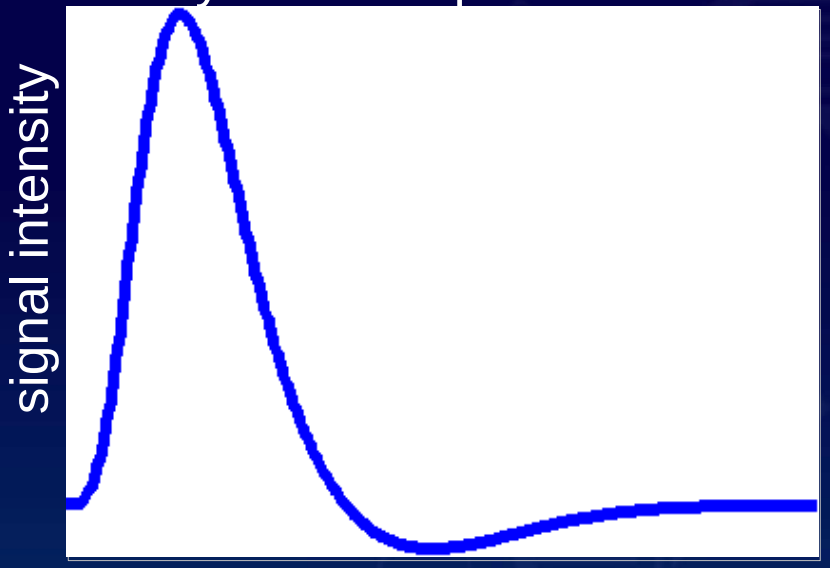


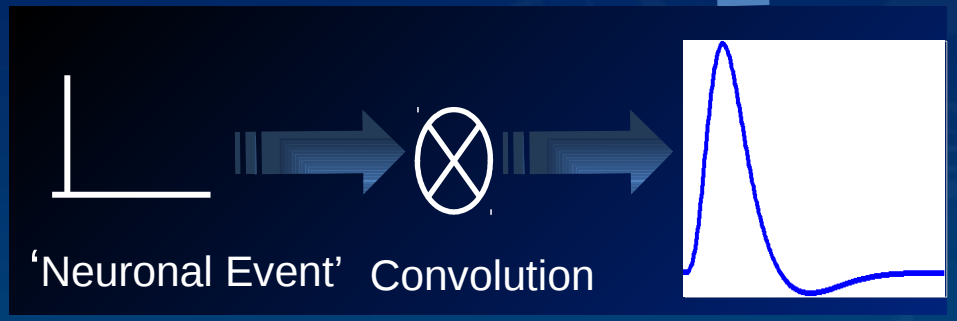
Increased flow

- Increased local flow
- Increase : ratio
- Increased MR signal

BOLD system output to 'impulse'

'Hemodynamic response function'





Summary

PET

- Uses radioactive tracers
- Low temporal and medium spatial resolution
- Measures *regional cerebral blood flow* (rCBF)
- Many tracers can be used (not just H2O15)

fMRI

- Magnet in high static field (=safety issues)
- Non-invasive
- High spatial (mm), medium temporal (ms to s) resolution
- Measure *local blood oxygenation levels*

Both methods measure the *results* of neuronal activation, rather than the neuronal signal itself.

End of presentation

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Module Resources: Imaging Basics

- Journal Articles

- Attwell, D. & Laughlin, S.B. (2001). An energy budget for signaling in the grey matter of the brain. *Journal of Cerebral Blood Flow & Metabolism* **21,** 1133–1145; doi:10.1097/00004647-200110000-00001

- Logothetis, N. (2008). What we can do and cannot do with fMRI. Nature, 453, 869-879 doi: 10.1038/nature06976