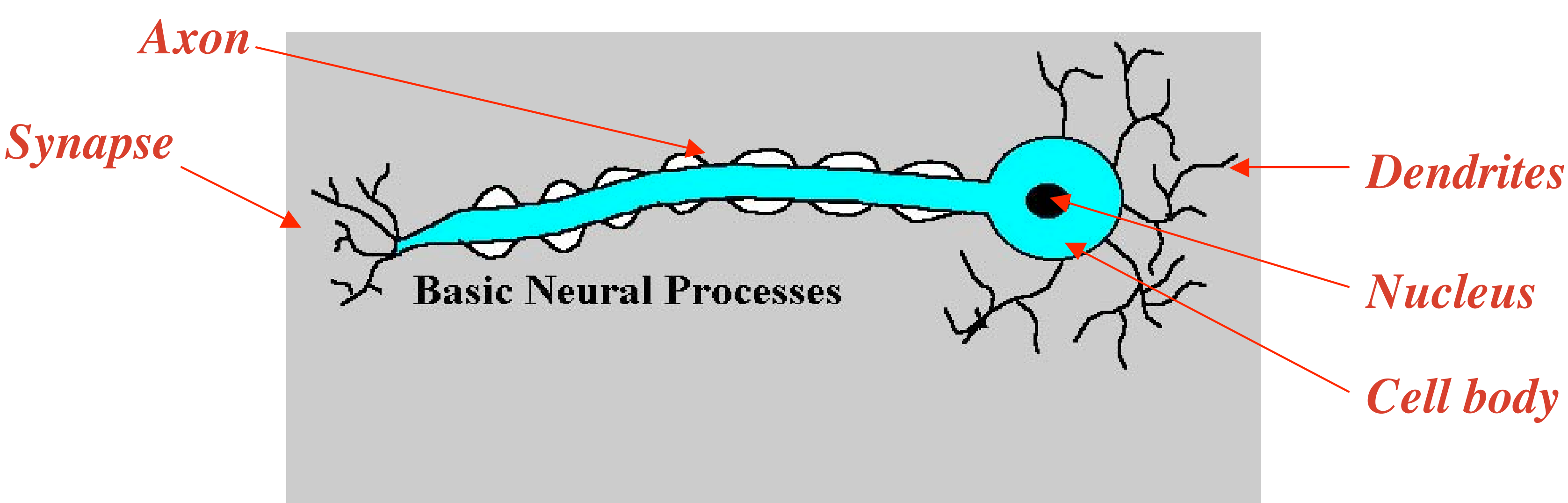
Functional neuroimaging

- Imaging brain function in real time (not just the structure of the brain).
- How?

The brain is *bloody* & *electric*

- Blood
  - **increase in neuronal activity → increase in metabolic demand for glucose and oxygen → increase in cerebral blood flow (CBF) to the active region**
- Electricity
  - **the brain works because neurons communicate with each other and they do this by sending out tiny electrical impulses**



Non-invasive recording from human brain (Functional brain imaging)

Hemodynamic techniques

- Positron emission tomography (PET)
- Functional magnetic resonance imaging (fMRI)

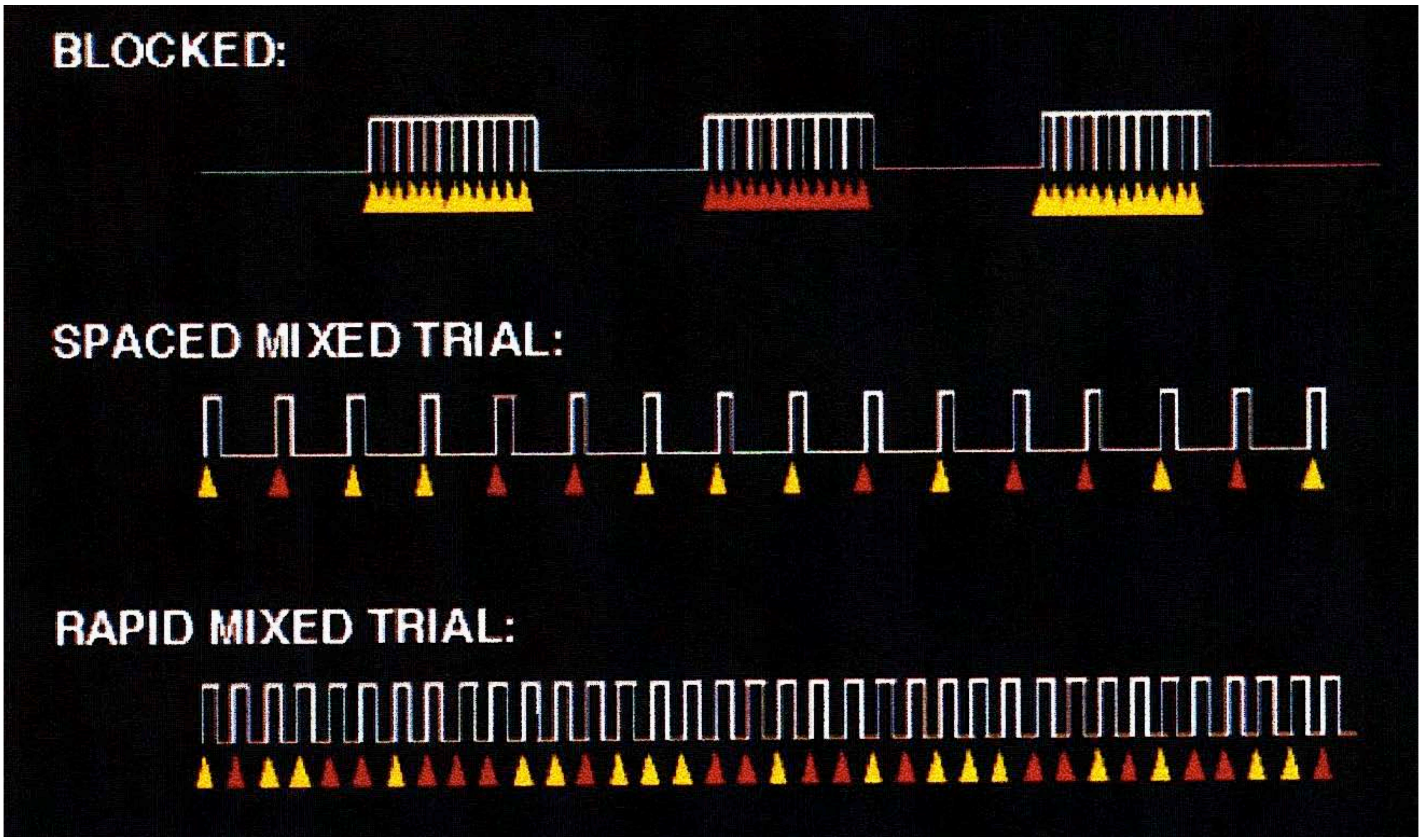
Excellent spatial resolution (~1-2mm)
Poor temporal resolution (~1sec)

Electro-magnetic techniques

- Electro-encephalography (EEG)
- Magneto-encephalography (MEG)

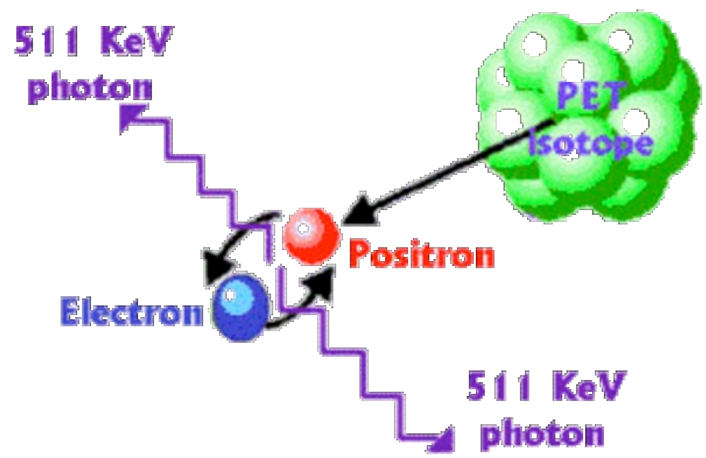
Poor spatial resolution (~1cm)
Excellent temporal resolution (<1msec)

Experimental designs for hemodynamic techniques



PET (Positron Emission Tomography)

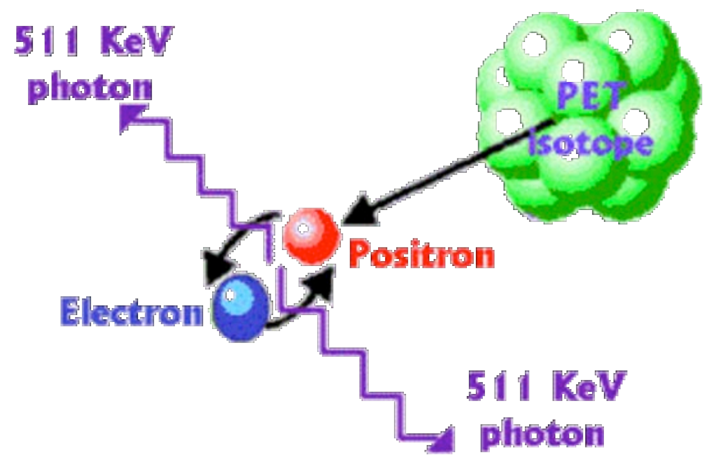
- Radioactive labeling of some compound that is familiar to the body (such as glucose or water).
- The radioactive material is administered to the subject.
- PET images the electromagnetic radiation induced by the decay of the PET radioisotopes.
  - The chosen radioactive material must have a short half-life.



- PET radioisotopes emit a positron (a positively charged electron) in the process of decay. When this positron collides with an electron, the 2 particles annihilate each other, and produce 2 photons traveling in opposite directions. This induces electromagnetic radiation which is what can be detected externally and is used to measure both the quantity and the location of the positron emitter.

PET (Positron Emission Tomography)

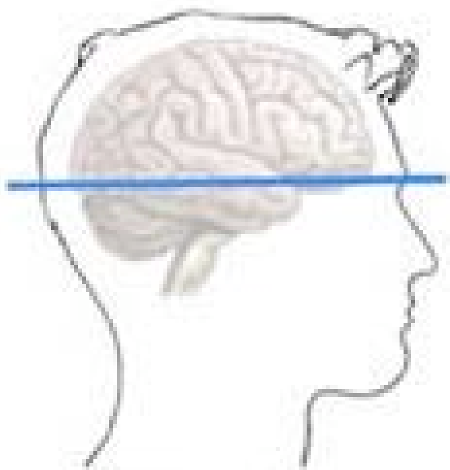
- Dependent measure: regional Cerebral Blood Flow (rCBF).
- Spatial resolution about 4mm throughout the brain.
- Temporal resolution very bad (~30-40 sec).
  - **Randomization is impossible (trials cannot be distinguished from each other).**
  - **Blocked design is necessary.**



Basics of MRI

- Our bodies are mostly water and have a high concentration of hydrogen nuclei.
- The nuclei of hydrogen atoms (called protons) normally point randomly in different directions. However, when exposed to a strong static magnetic field, the nuclei line up in parallel formation, like rows of tiny magnets.
- In an MRI set-up, a strong external static magnetic field is applied across the brain in order to line up the hydrogen nuclei. (This field can be up to 80 000 times stronger than the earth's magnetic field.)
- Then this parallel formation, called *equilibrium*, is disturbed by sending out radio waves from the MRI machine
- As the hydrogen nuclei fall back into alignment, they produce a detectable radio signal.
- MRI signal decay rates (T2s) are different for different biological tissues. For example, tissues that contain little or no hydrogen (such as bone) appear black. Those that contain large amounts of hydrogen (such as the brain) produce a bright image.

Basics of MRI



Level
of section

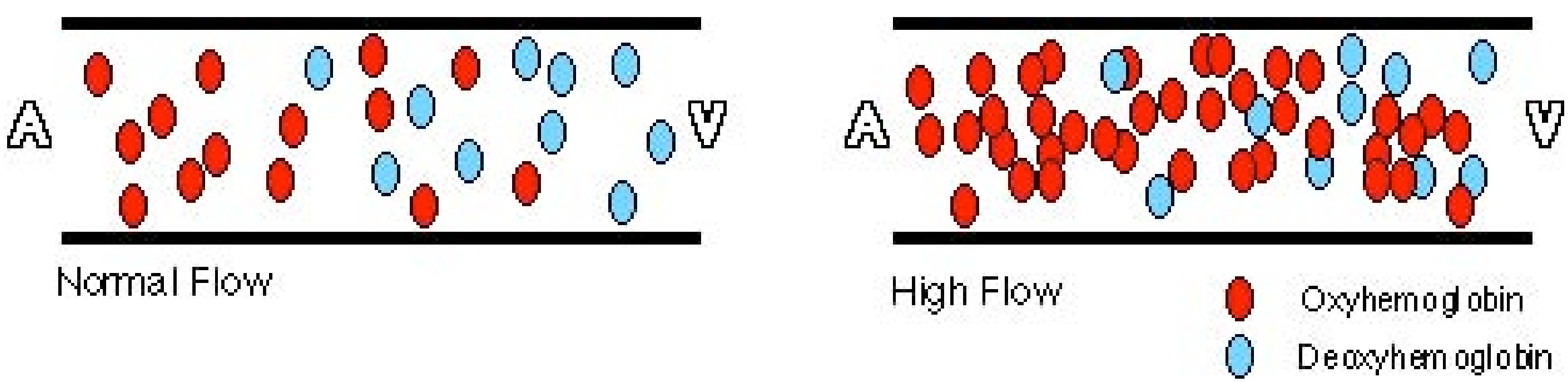
MRI of brain

Functional MRI (fMRI)

- MR has the capability to measure parameters related to several neural physiological functions, including:
  - **changes in various metabolic byproducts**
  - **blood flow**
  - **blood volume**
  - **blood oxygenation**

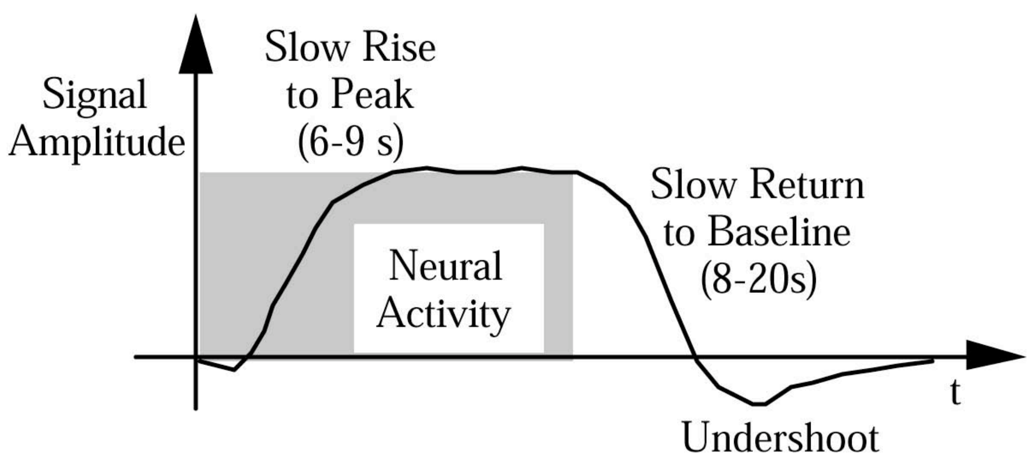
Functional MRI (fMRI)

- Blood Oxygenation Level Dependent (BOLD) signal
  - **Blood is more oxygenated in an activated region of the brain than in a nonactivated region.**
  - **Oxyhemoglobin and deoxyhemoglobin differ in their magnetic susceptibility: Deoxy Hb has a higher magnetization decay rate than does oxy Hb.**



Functional MRI (fMRI)

- No radioactive tracers are needed.
- Spatial resolution: 3-6mm (in most applications).
- Temporal resolution: in the order of seconds.
  - **Fast enough to distinguish between trials (i.e. event-related designs and randomization are possible)**
  - **Not fast enough to distinguish between the activation patterns associated with different stages of stimulus processing.**
- Hemodynamic lag (3-6 seconds):



The subtraction method

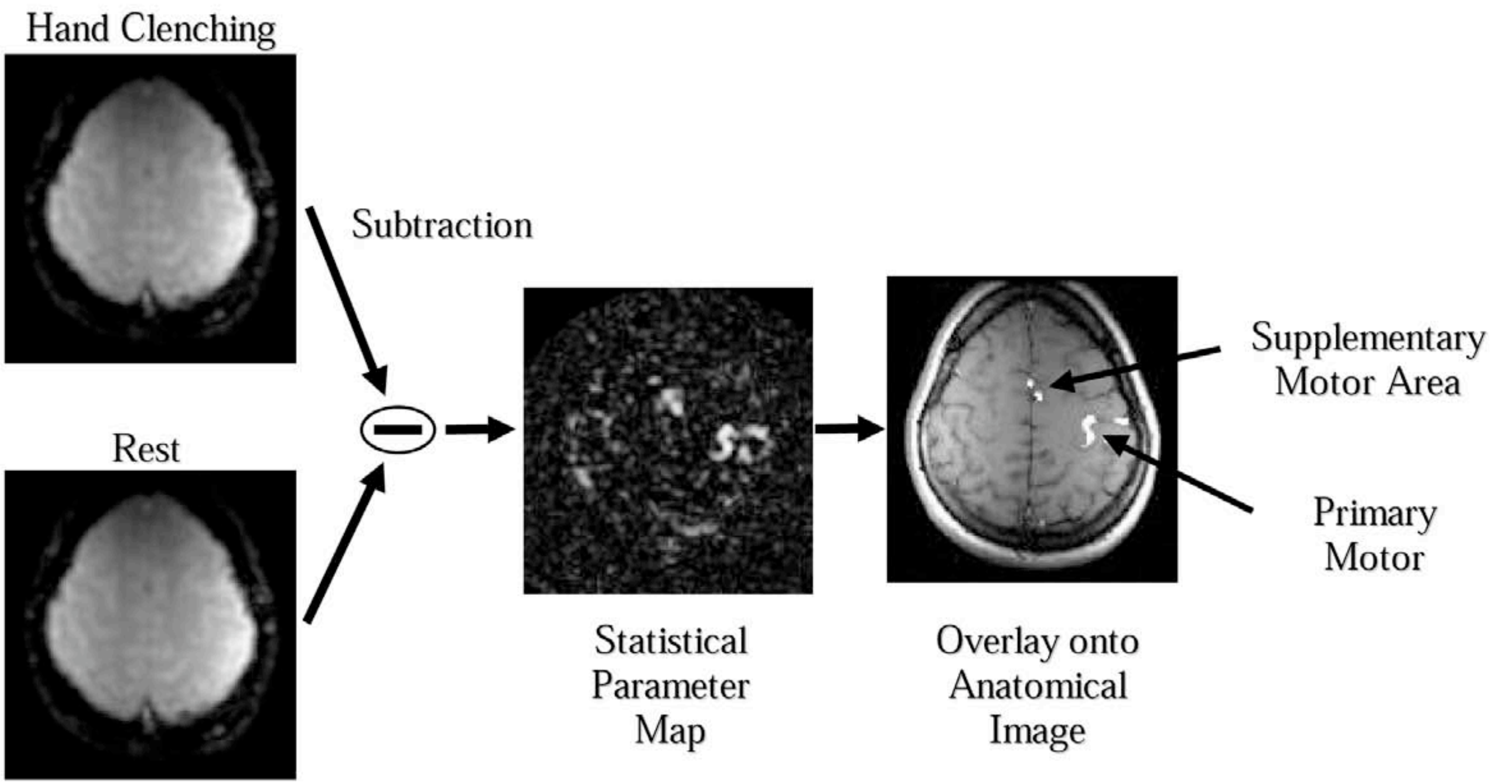


Figure 9. Graphical description of a functional MRI experiment: images from two behavioral conditions are subtracted to yield regions of brain activity. In this case, a hand clenching task was used to define the primary and supplementary motor control areas in the brain.