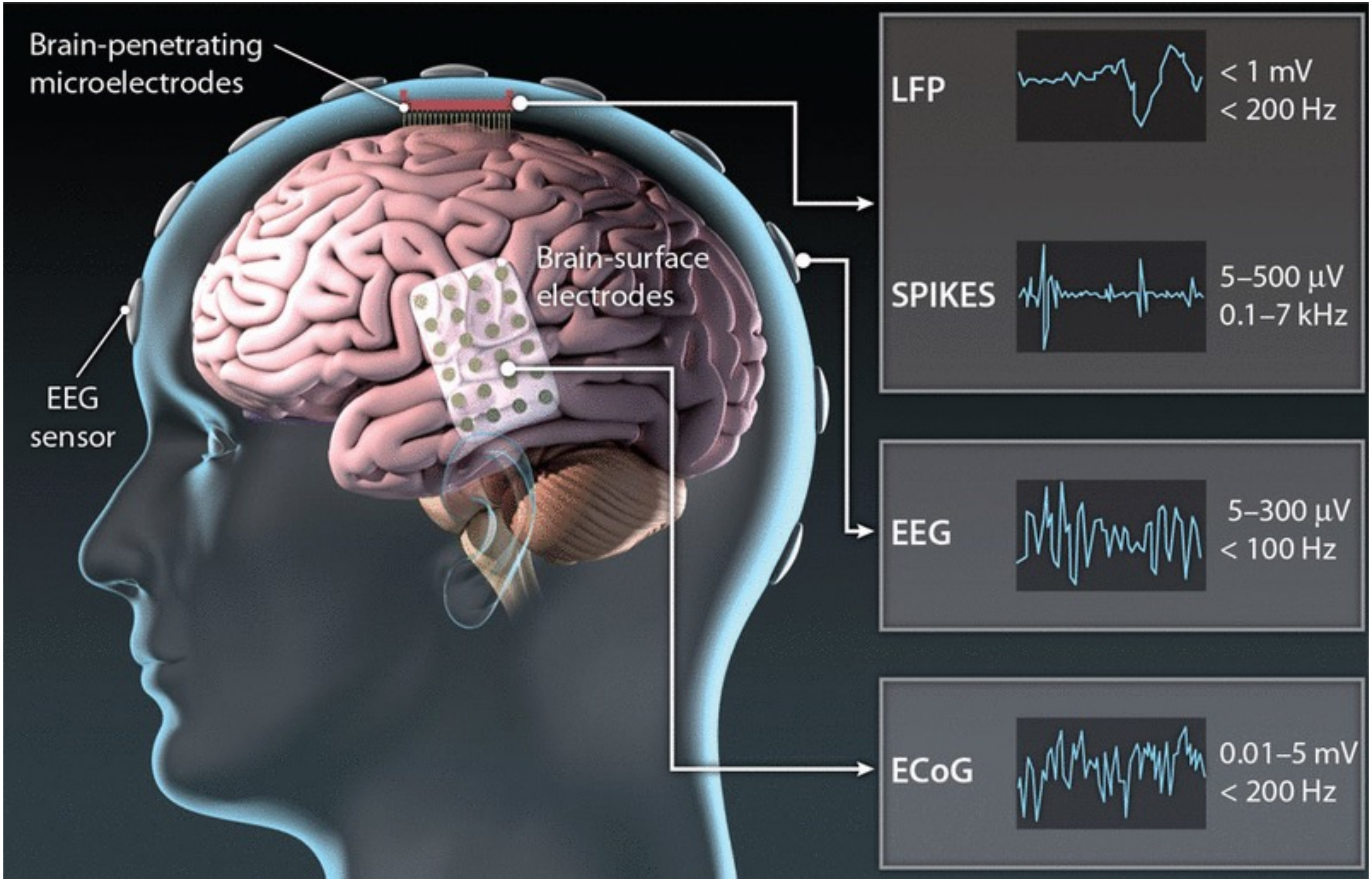
Brain Signal Acquisition

Background

- The brain communicates using spikes-- produced when the neuron receives enough input current from other neurons via synaptic connections.

- Recording brain activity are based on detecting changes in electrical potentials in neurons
  - invasive techniques based on implanting electrodes

- Or on detecting changes in large populations of neurons
  - noninvasive techniques such as electroencephalography or EEG



Brain-penetrating microelectrodes
Brain-surface electrodes
EEG sensor
LFP
< 1 mV
< 200 Hz
SPIKES
5–500 µV
0.1–7 kHz
EEG
5–300 µV
< 100 Hz
ECoG
0.01–5 mV
< 200 Hz

Recording signals from brain

Invasive Approaches:

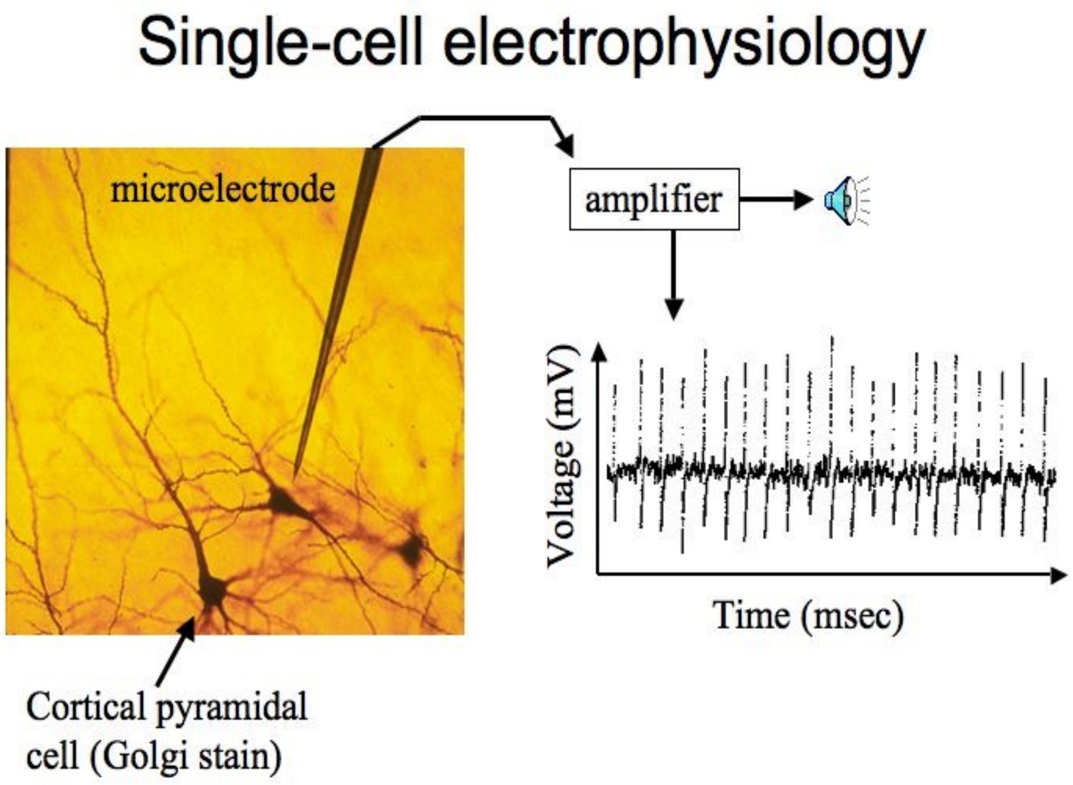
- Techniques that allow recording from individual neurons in the brain are typically invasive.

- They involve some form of surgery,
  - A part of the skull is removed, an electrode or implant placed in the brain, and the removed part of the skull then replaced.
  - The recording itself is not painful because the brain has no internal pain receptors, but the surgery and recovery process can cause pain and involves risks such as infection.

- A major advantage of invasive recordings is that they allow recording of action potentials at the millisecond timescale.

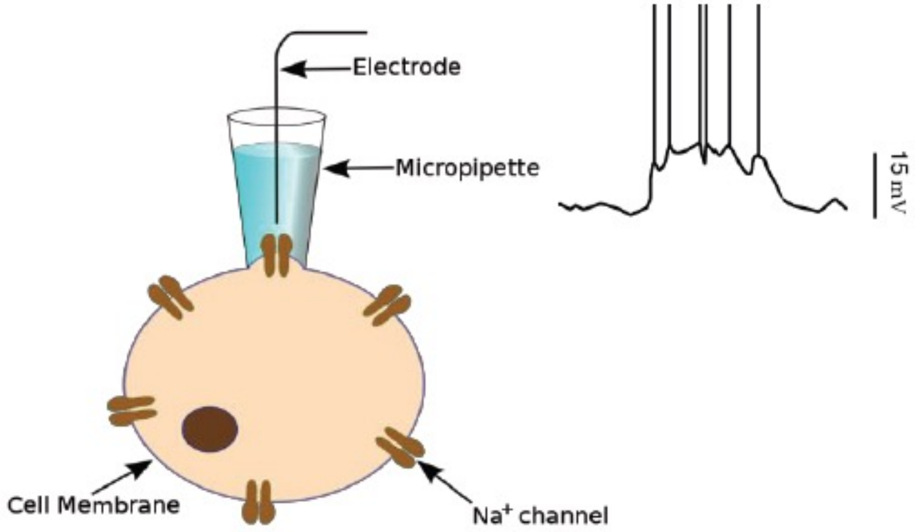
Invasive Approaches

- **Microelectrode:**
- A *microelectrode* is simply a very fine wire or other electrical conductor used to make contact with brain tissue.
- A typical electrode is made of tungsten or platinum- iridium alloy and is insulated except at the tip, which measures around 1µm in diameter (A neuron's cell body diameter is in the range of tens of µm).



Invasive Approaches

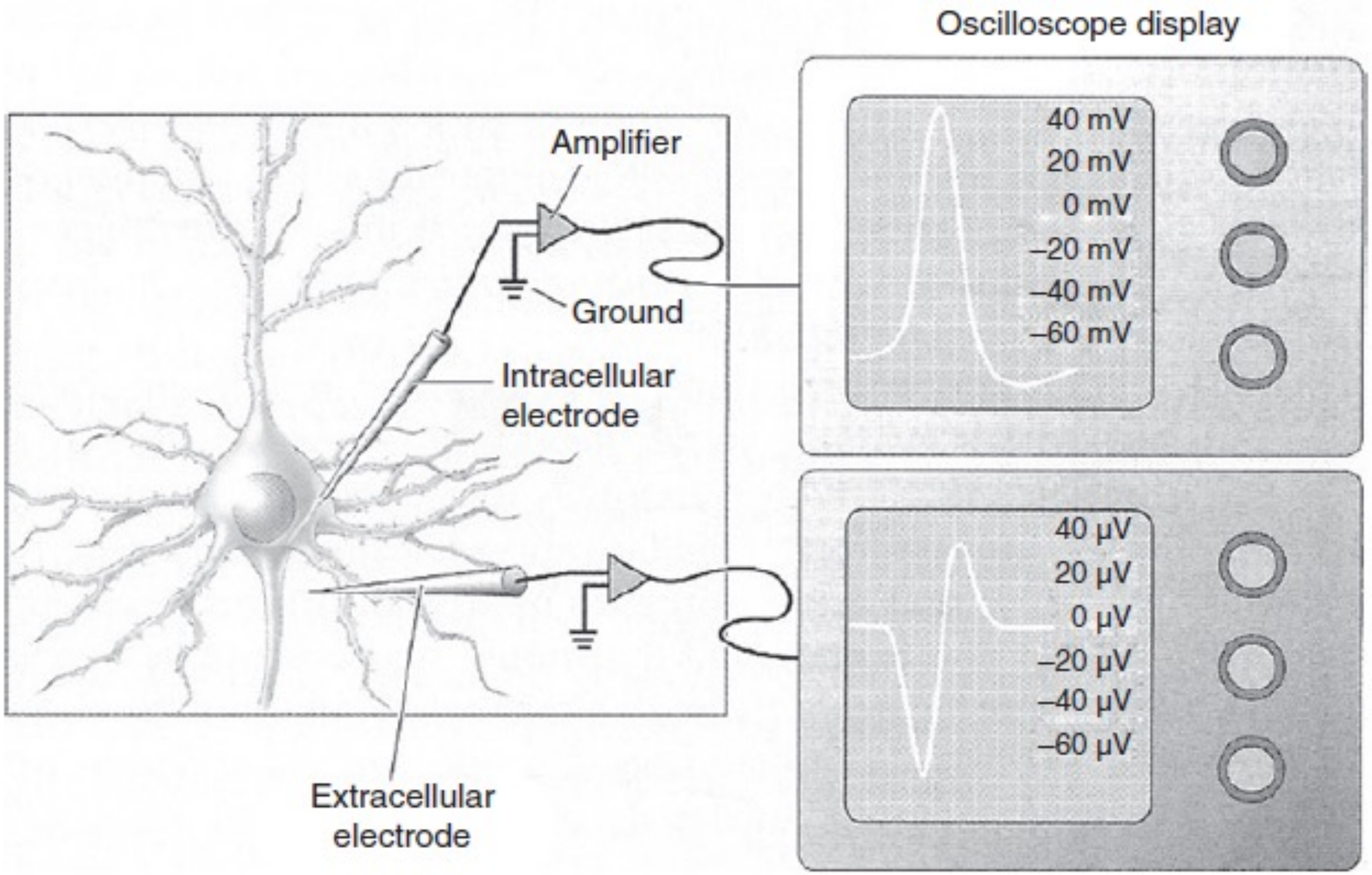
- **Intracellular Recording:**
- Measures the voltage or current across the membrane of the neuron.
- The most common technique, known as *patch clamp recording*.
- Very Delicate → Intracellular recordings are typically performed only on slices of brain tissue



Invasive Approaches

- **Extracellular Recording:**
- Recording of a single neuron (or single“unit”): a tungsten or platinum-iridium microelectrode with a tip size of less than 10 microns is inserted into the target brain area.
- The magnitude of the recorded signal is usually less than a millivolt and thus requires the use of amplifiers to detect the signal.
- The signal from the amplifier is fed to a computer, which performs additional processing such as filtering noise and isolating the spikes (action potentials).

Invasive Approaches



(from Bear et al., 2007).

Invasive Approaches

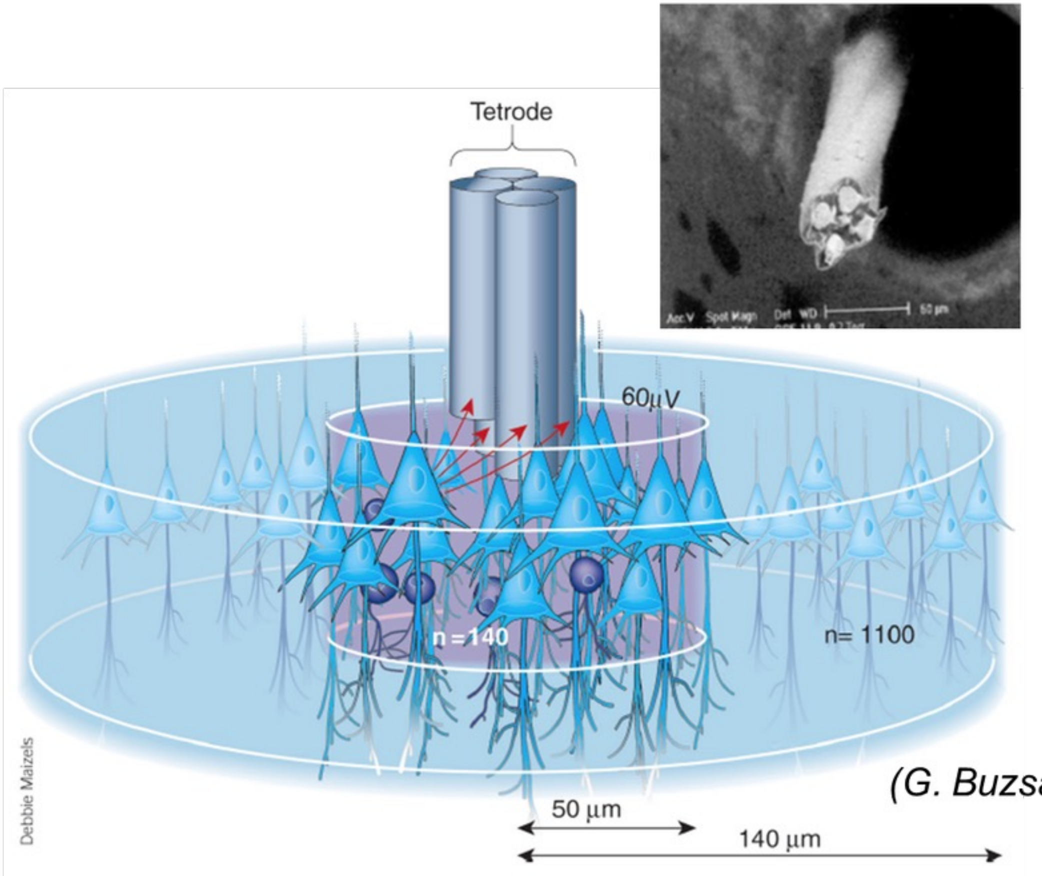
- When the neuron produces a spike, positive ions flow away from the extracellular electrode into the neuron, causing the initial negative deflection in the display. This is followed by a positive deflection as the action potential decreases and positive charges flow out of the neuron toward the extracellular electrode.

Invasive Approaches

Tetrodes and Multi-Unit Recording:

- To record from multiple neurons simultaneously by using more than one electrode.
- Four wires are tightly wound together in a bundle.

Tetrode recordings allow the monitoring of single neurons during behavior

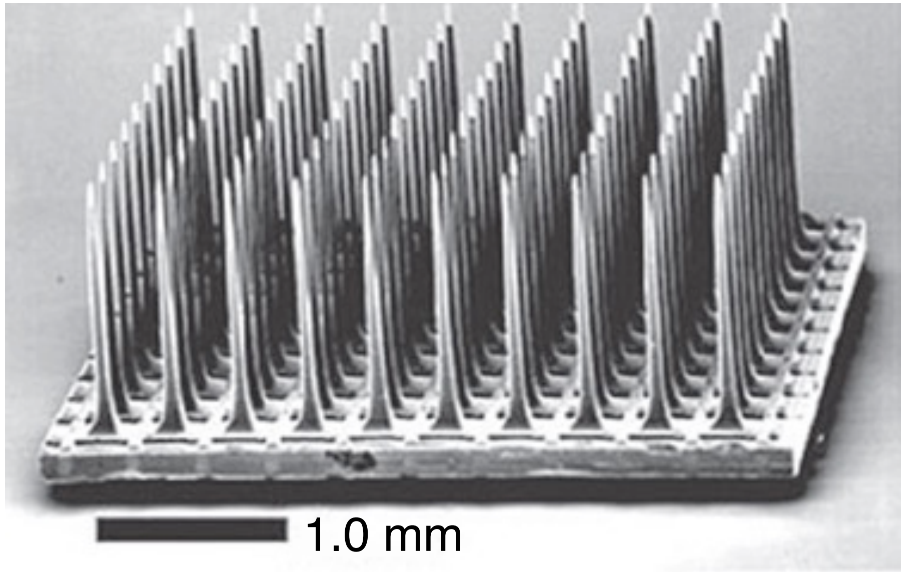


(G. Buzsáki, 2005)

Invasive Approaches

Multielectrode Arrays:

- To record from larger numbers of neurons, microelectrodes can be arranged in a grid-like structure to form a multielectrode array of $m \times n$ electrodes.



(adapted from Hochberg et al., 2006).

Invasive Approaches

- The most common types of implantable arrays are microwire, silicon-based, and flexible microelectrode arrays
- Increased spatial resolution
- The ability to record simultaneously from several dozens of neurons
- Opens the door to extracting complex types of information such as position or velocity signals that could be useful for controlling prosthetic devices.