Chapter 7, Neural Coding

We start with a simple proposition:

There is no grandmother cell, and there is no yellow Volkswagen cell.

That is to say:

There is no single neuron signalling: I have detected grandmother.

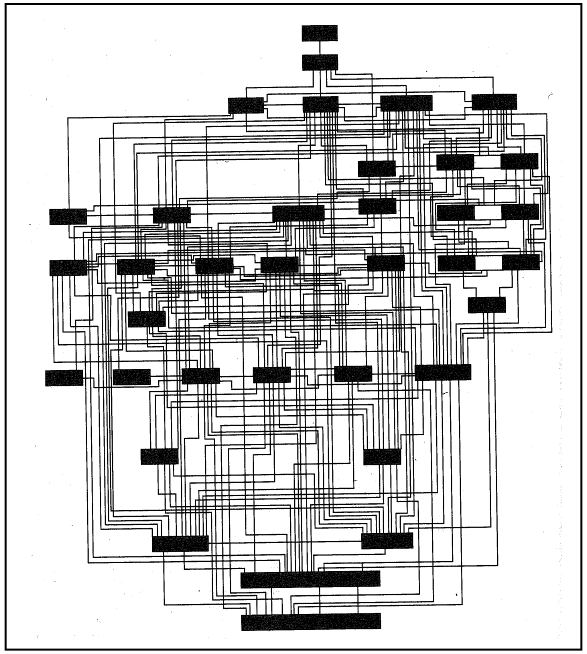
That is good because we want graceful degradation.

(What would happen if there were a grandmother cell and that cell happened to die – would grandmother go undetected?)

The presence of grandmother is accompanied by neural activity in many neurons. If one of these neurons die, some aspect of grandmother might become ever so slightly blurred.

Chapter 7, Neural Coding, 7.2 Coding in space: ensemble codes

Humans have some 30 cortical areas devoted to different aspects of vision. These are connected according to the following scheme:

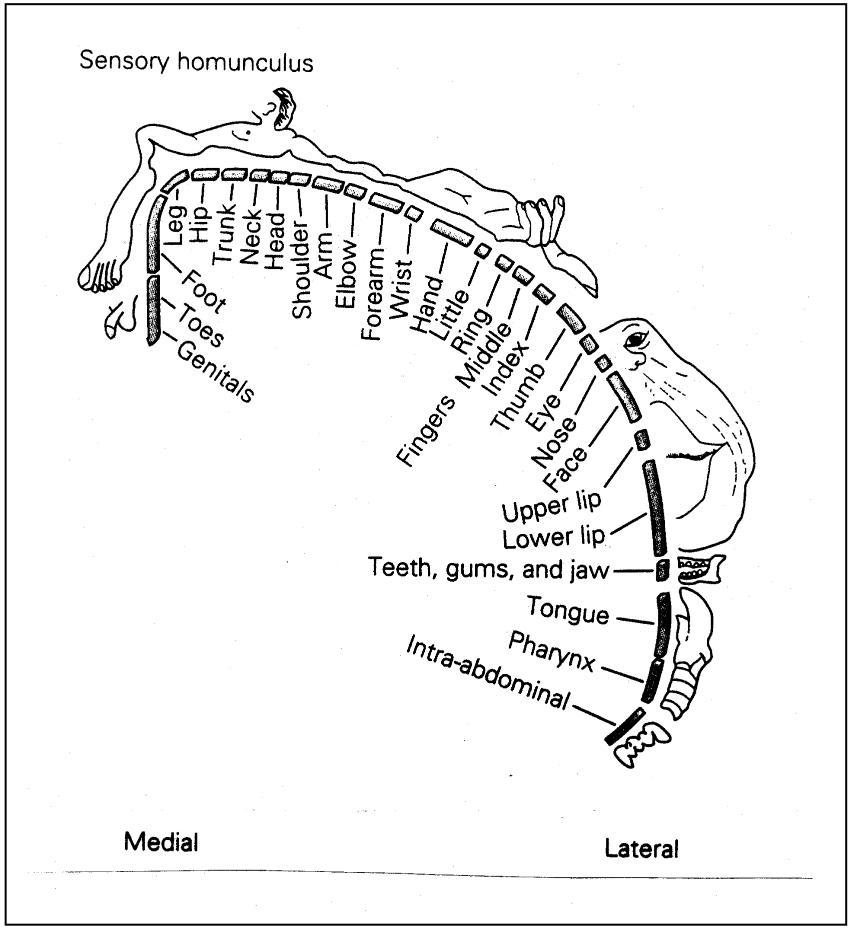


(Felleman and van Essen, Distributed hierarchical processing in the primate cerebral cortex, *Cerebral Cortex*, 1991, 1-47)

Some of these areas “treat” form, others movement. Other aspects of vision like colour have their own “specialist” areas. Whatever we look at, there will be active neuronal populations and their activity must be bound together to form a complete representation. Humans rely on vision!

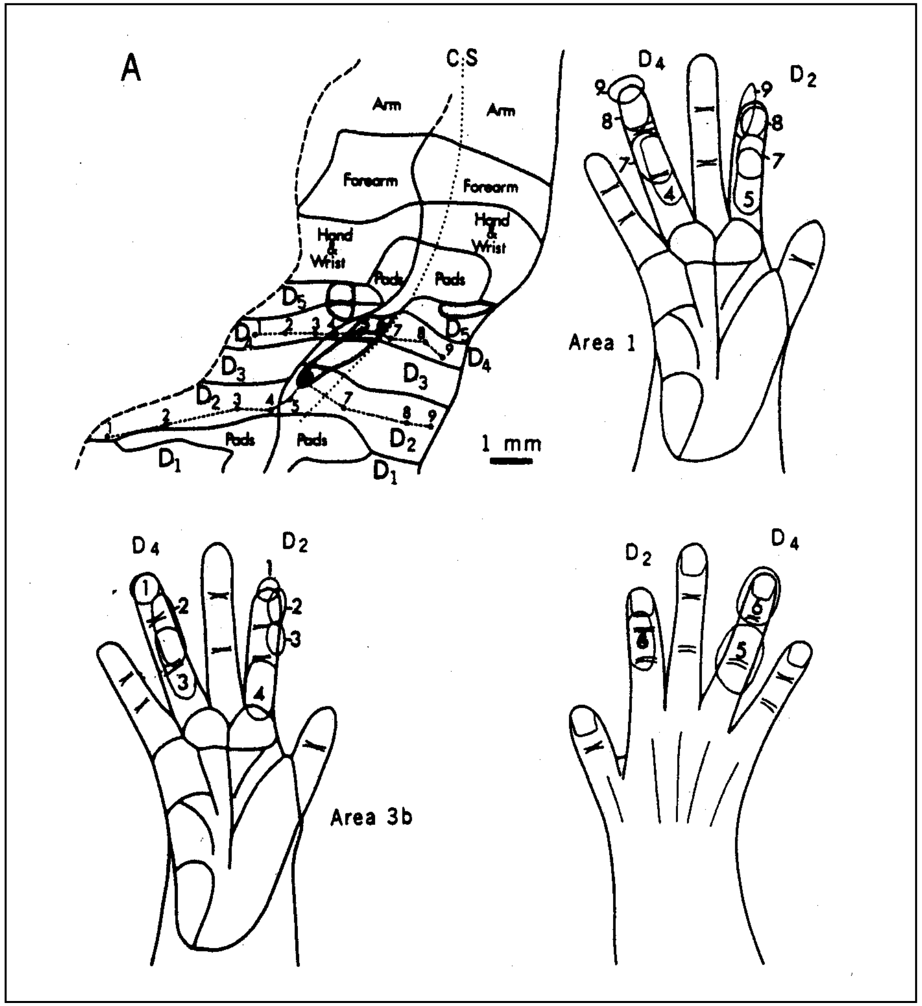
Chapter 7, Neural Coding 7.2 Coding in space: ensemble codes

We have maps of ourselves and of common stimuli from our surrounding. The most commonly known is the homunculus. The sensory homunculus is seen below, the motor homunculus is similar.
(from Kandel et al. Eds. Principles of Neural Science, 2000, 344)



Chapter 7, Neural Coding 7.2 Coding in space: ensemble codes

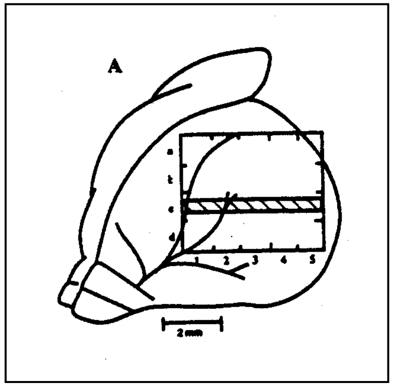
The sensory maps are known in more detail, particular the macaque's maps
(from Kaas et al., Multiple representations of the body within the primary somatosensory cortex o primates, Science 1979, 521-523.)

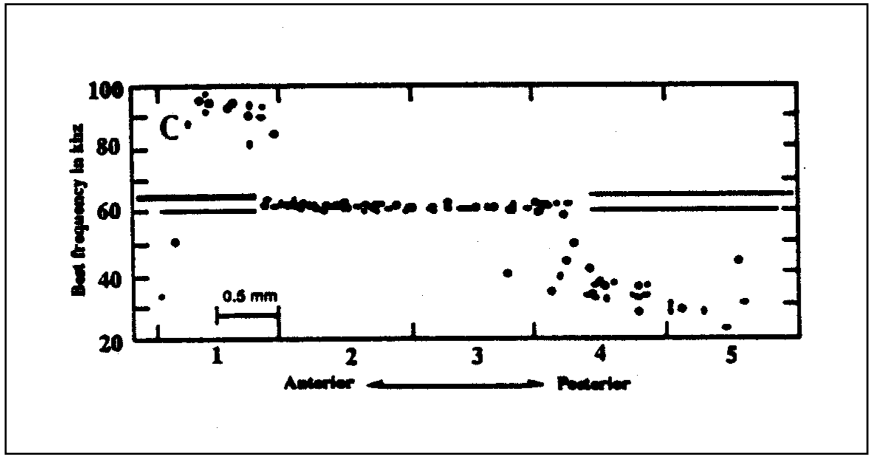


Chapter 7, Neural Coding 7.2 Coding in space: ensemble codes

Other animals have maps too. Bats have their own built-in sonar and rely on hearing. Below is the tonotopic map of a bat of the species *Pteronotus parnetti rubiginosus*

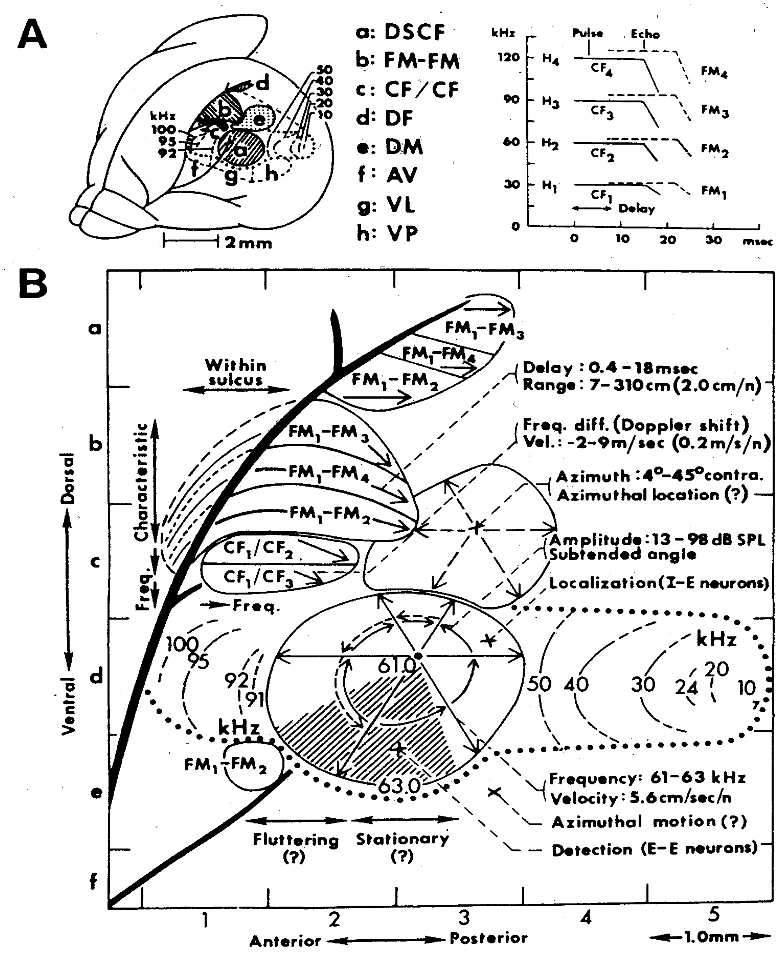
From Suga andJenDisproportionate Tonotopic Representation for Processing CF-FM Sonar Signals in the Mustache Bat Auditory Cortex, Science, 1976, 542-544.





Chapter 7, Neural Coding 7.2 Coding in space: ensemble codes

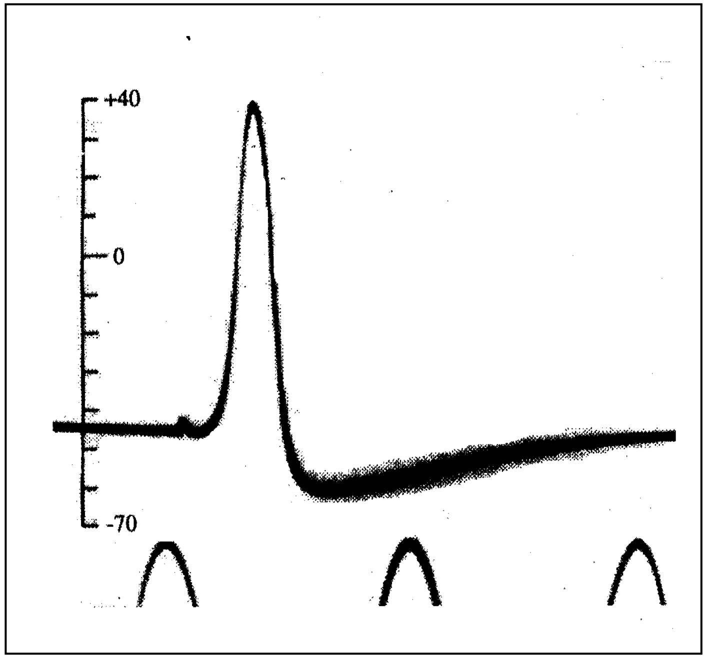
The bat charts its surrounding with the aid of cortical maps
Ffrom Suga in Edelman et al. eds. *Dynamic Aspects of Neocortical Function*, 1985.



Chapter 7, Neural Coding 7.3 Coding with volts and chemicals: neural state code

Real neurons are complex structures. There are good reasons to believe that substantial information processing goes on within a single neuron. For the time being we only consider the weighted sun and squashing mechanism as a model for the internal workings of the neuron.

Real neurons produce action potentials in the form of voltage spikes that travel down the axon. The spikes are very similar in form so the only attribute of the spike that can carry information is its timing.



An action potential in the squid giant axon.
The potential in the extracellular fluid is chosen as 0. The inside of the neuron membrane has a negative resting potential, but its potential rapidly rises to a positive value and then very quickly reverses to a value below the resting potential. The distance between the peaks at the bottom is 2 ms.
From Hodgkin and Huxley, Action potentials recorded from inside a nerve fiber, Nature, 1939, 710-711

The action potential is very similar in a human neuron.

Chapter 7, Neural Coding 7.4 Coding in time: temporal and rate codes

We don’t have a built-in absolute time reference. So the timing of a spike must be related to one or more other spikes.

A spike’s timing can be related to other spikes on the same axon. This offers straightforward interpretations.

A spike’s timing may also be related to other spikes on the axons of other neurons. This is more difficult to discuss but offers additional possibilities.

Chapter 7, Neural Coding 7.4 Coding in time: temporal and rate codes

Temporal integration, rate coding or frequency coding

The number of spikes in a sliding time interval is one scalar value that may be used to represent the activity of a neuron.

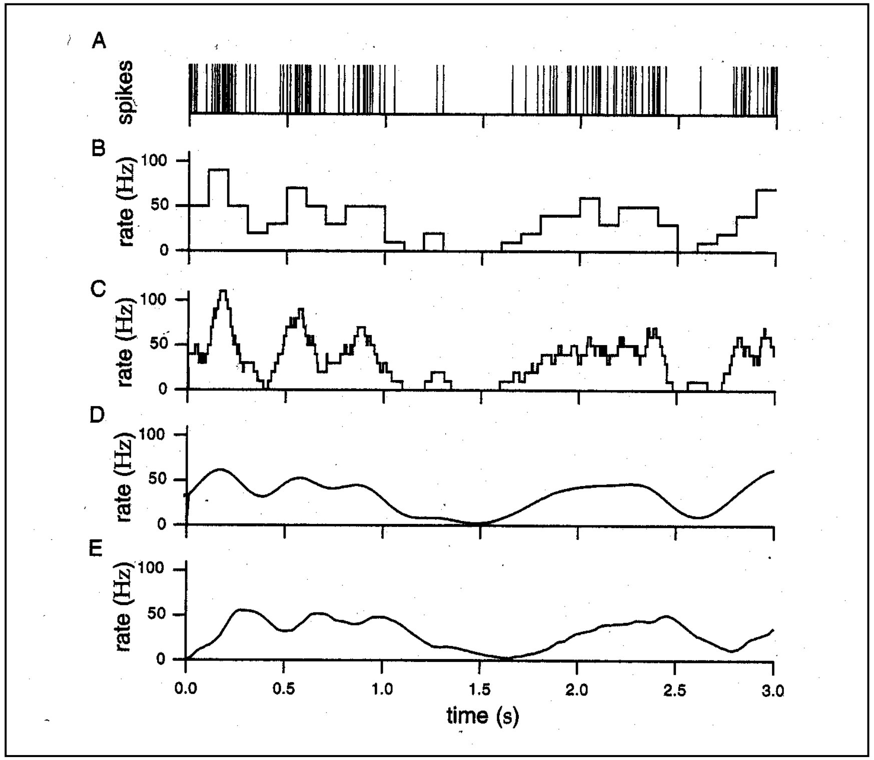
Counting the number of spikes constitutes temporal integration.

The resulting number of spikes per time unit constitutes rate coding or frequency coding.

This is the same coding principle as in an FM radio!

Chapter 7, Neural Coding 7.4 Coding in time: temporal and rate codes

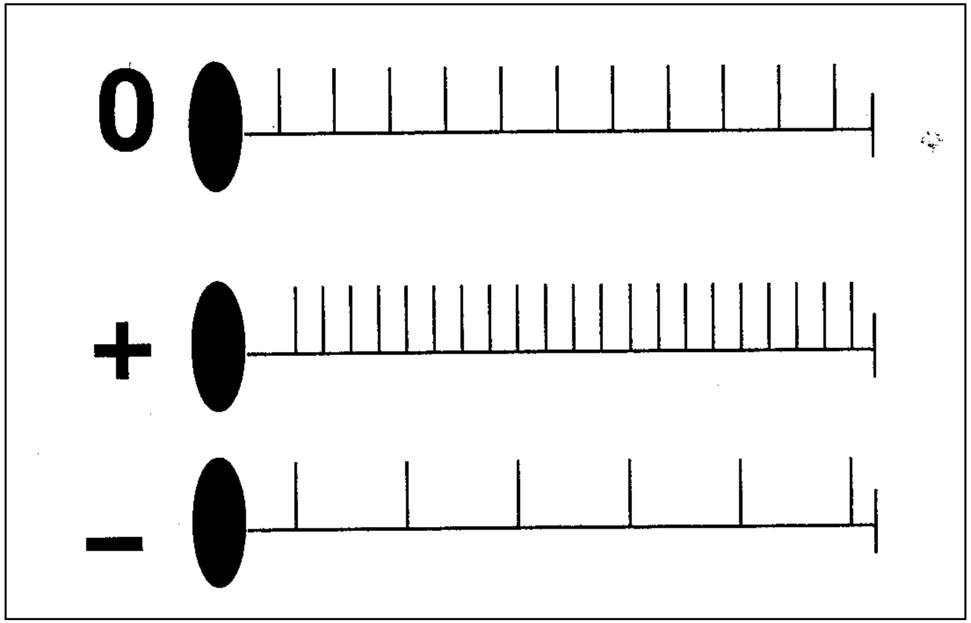
You obtain different rates with different procedures:



From Baddeley et al., Responses of neurons in primary and interiore temporal visual cortices in natural scenes, *Proceedings of the Royal Society of London*, 1997, 1775-1783.

Chapter 7, Neural Coding 7.5 Frequency coding

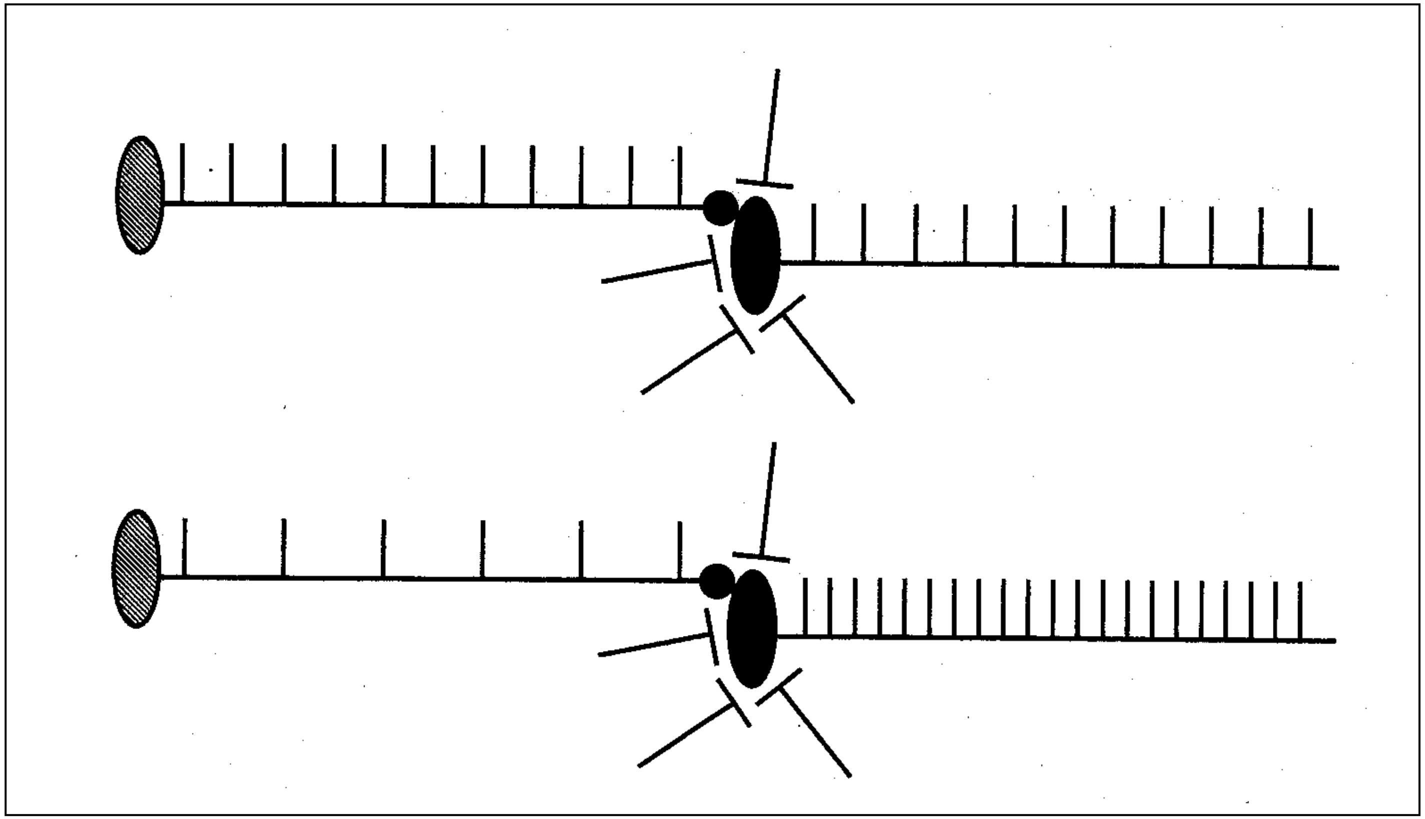
In some models state can have negative numbers. This then relates to rate codes as shown below:



From Lytton, p.115

Chapter 7, Neural Coding 7.5 Frequency coding

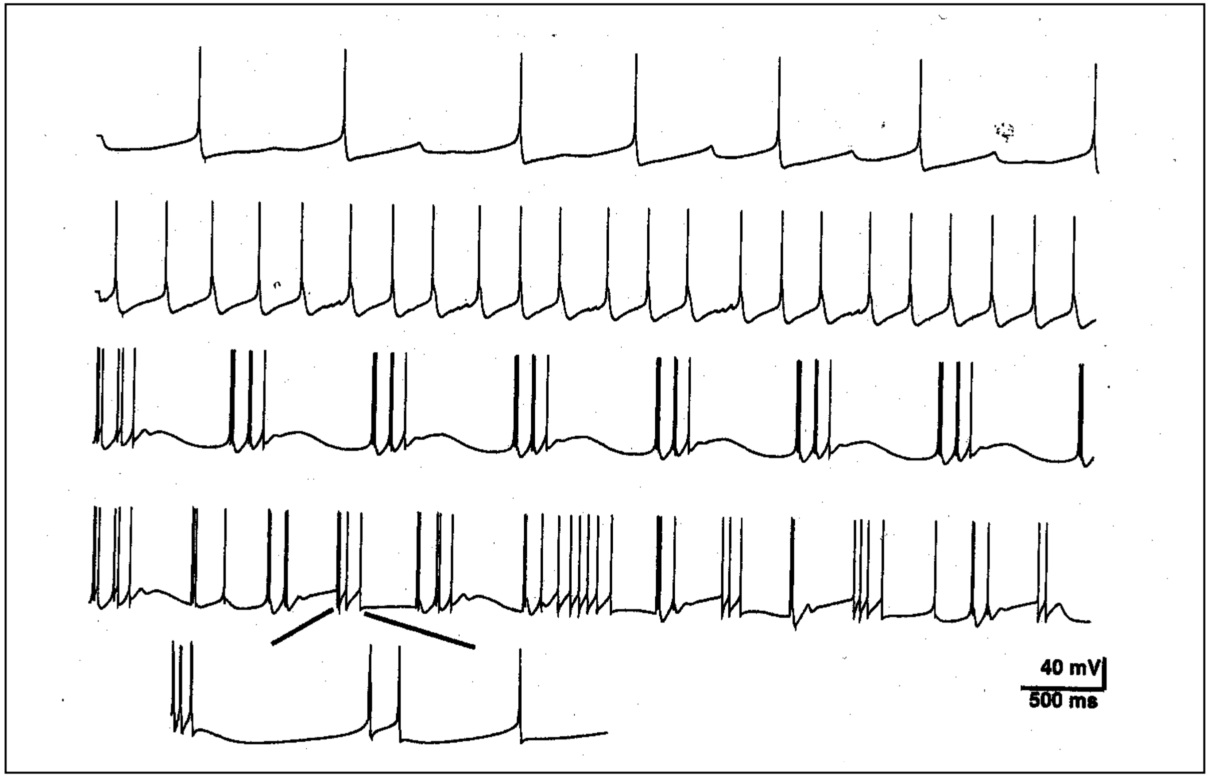
The influence of an inhibitory input on the frequency of spikes from a neuron:



From Lytton, p.116

Chapter 7, Neural Coding 7.5 Frequency coding

Real neurons provide complications for frequency coding though: they also have burst modes as shown in the lower traces below. What could these represent?



From Lytton p. 117

Chapter 7, Neural Coding 7.5 Frequency coding

Electroencephalography

It is possible to measure potentials outside the skull. These potentials represent the activity of large neuronal populations. They are called *field potentials*. There are rapid fluctuations in these potentials too, and they are also called spikes. It is an entirely different kind of spike than the action potential of a single neuron.

Lytton suggest they may represent epiphenomena, i.e. not be a part of neural information processing but rather be a byproduct.

Anyway it is useful for diagnostic purposes, e.g. for epilepsy.