Part III Cybernetics

Chapter 6 Concept Neurons

Chapter 7 Neural Coding

**Chapter 8 Our Friend the Limulus**

Chapter 9 Supervised Learning

Chapter 10 Associative Memory Networks

These chapters present classical artificial neural networks and the substance this course is concentrated on.

Two chapters are lacking in the book, one on **Unsupervised Learning** and one on **Reinforcement Learning** which in brain modelling are much more important than supervised learning, as I see it. We will, of course, discuss these topics too.
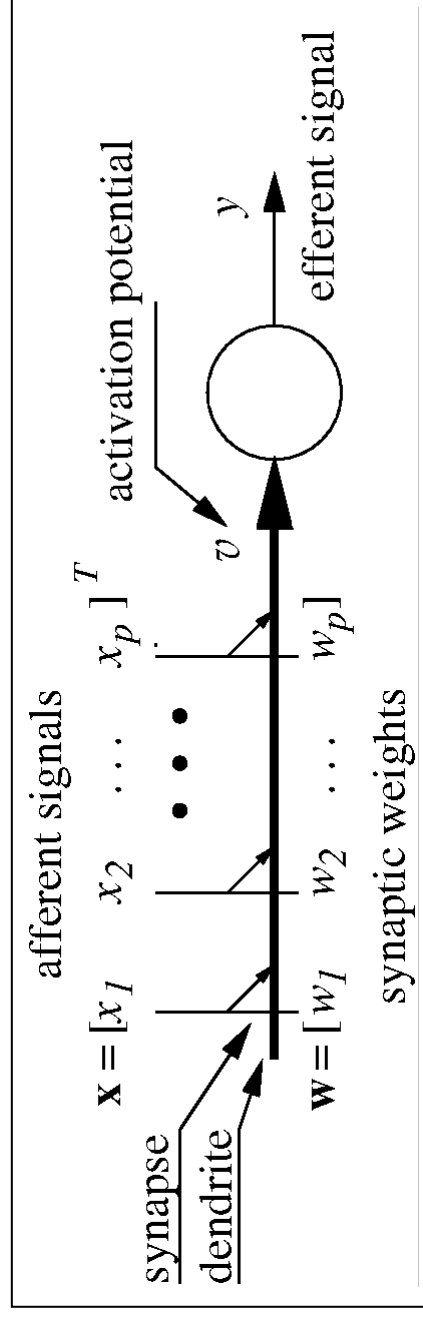
Chapter 6, Concept Neurons

The McCulloch-Pitts neuron from 1943 according to Lytton:

MP neuron

dendrite
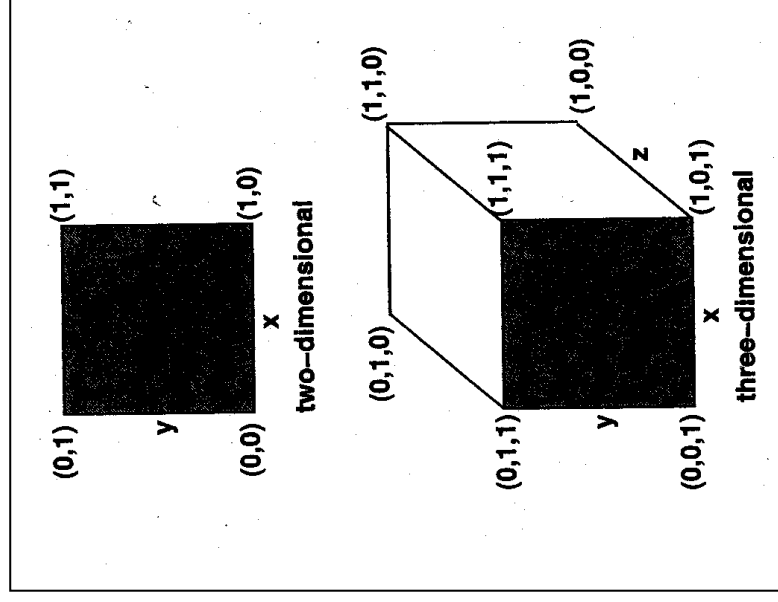(input)

axon
(output)

State

Summed Input
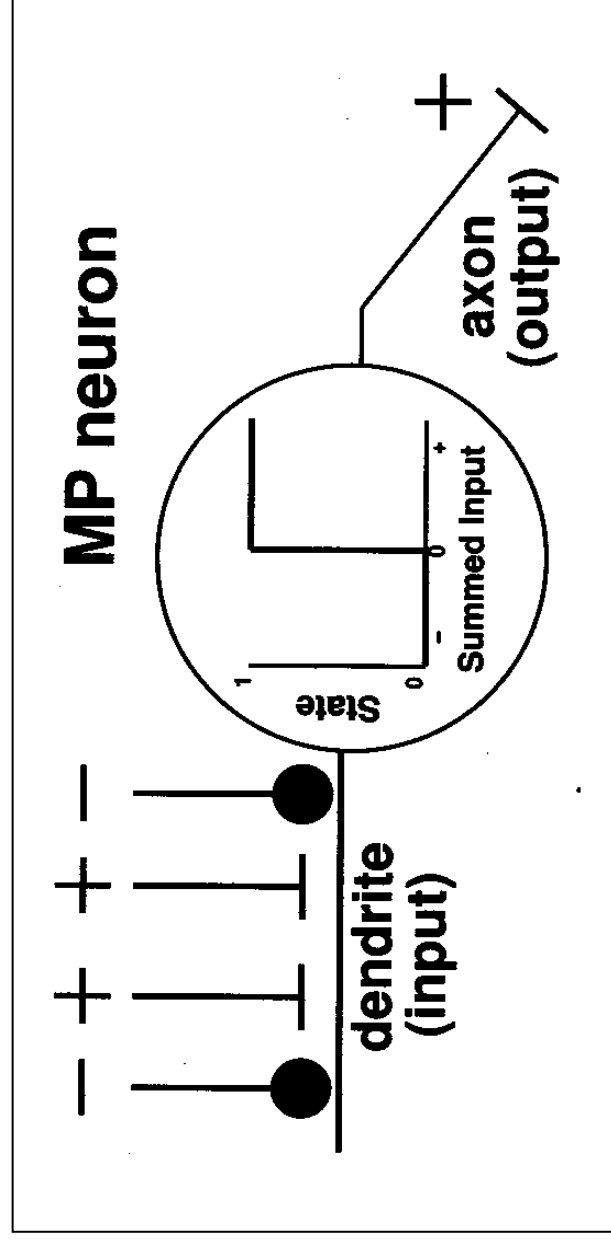
Chapter 6, Concept Neurons

We will draw neurons as below

afferent signals

$\mathbf{x} = [x_1 \quad x_2 \quad \dots \quad x_p]^T$

synapse

dendrite

$\mathbf{w} = [w_1 \quad w_2 \quad \dots \quad w_p]$

synaptic weights

activation potential

v

y

efferent signal

The synapses are drawn as arrows, which is our symbol for excitatory synapses.
The weighted sum of the afferents is called activation potential.
The nonlinearity, which is a part of almost all neuron models, resides in the circle.
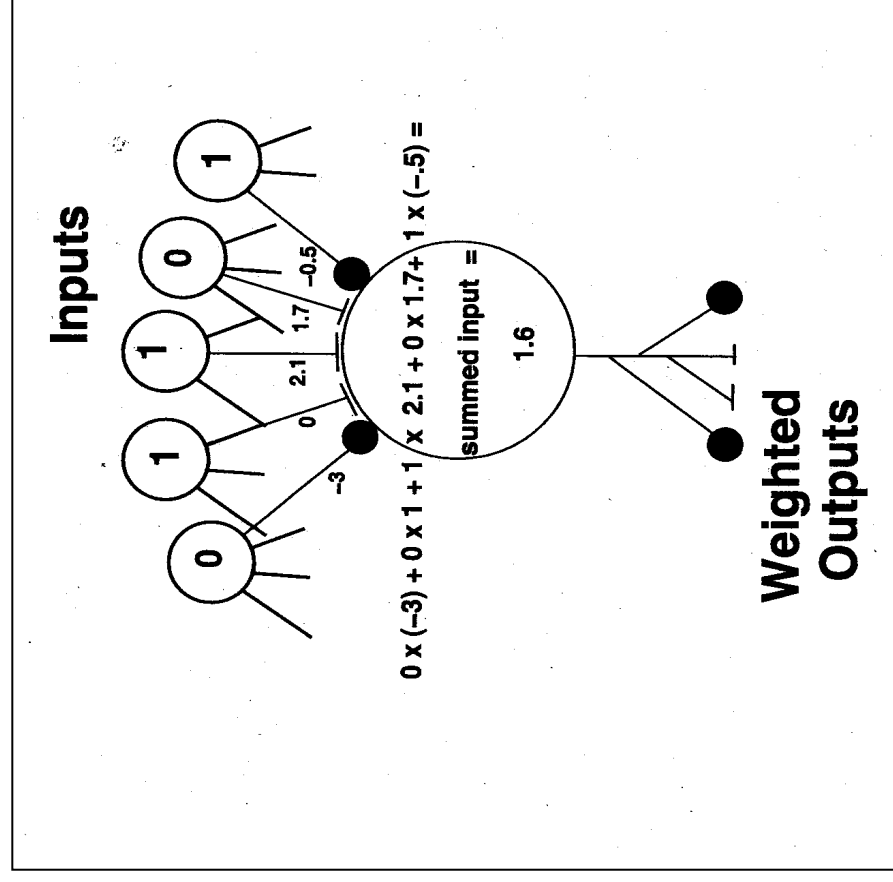
Chapter 6, Concept Neurons

A binary neuron will receive binary inputs from other binary neurons. The inputs collected in vectors can be illustrated in two and three dimensions. From there on we must generalize.
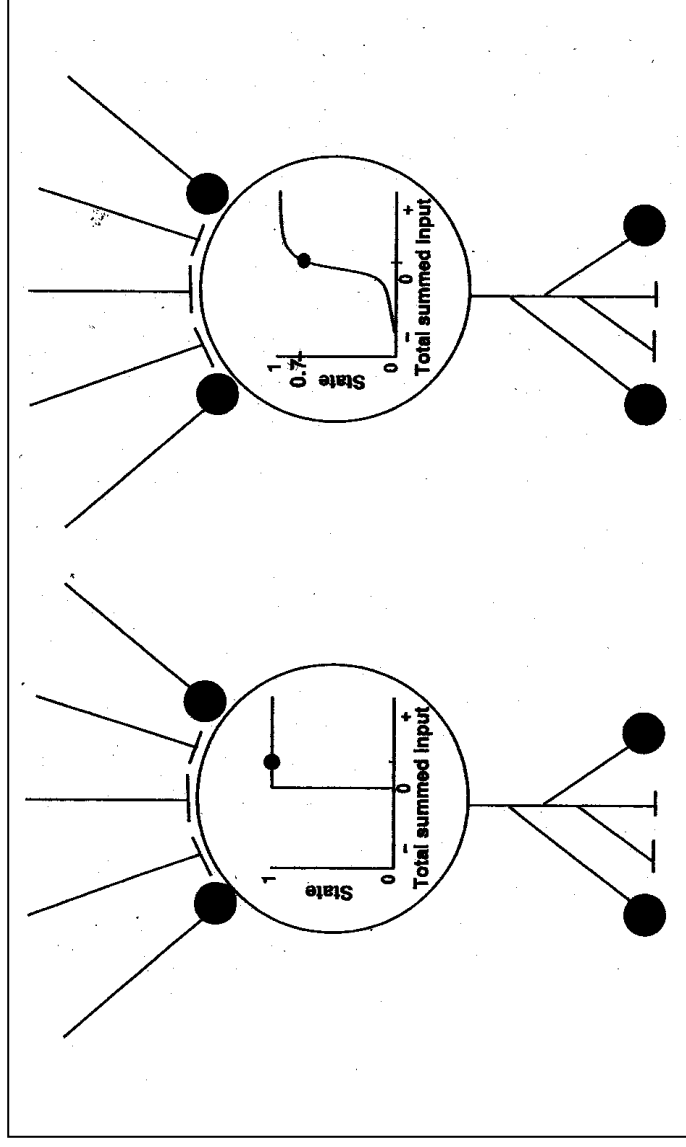

Lytton, fig 6.6

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Chapter 6, Concept Neurons

A "computing" neuron (Lytton, fig 6.2):

Inputs

$0 \times (-3) + 0 \times 1 + 1 \times 2.1 + 0 \times 1.7 + 1 \times (-.5) =$ summed input = 1.6

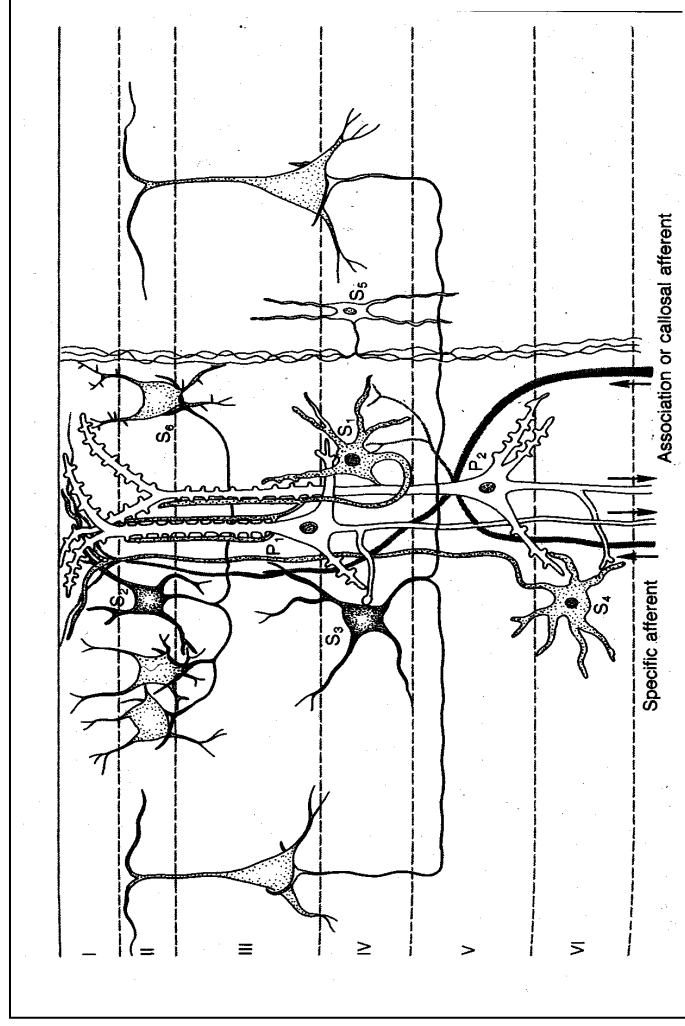**Weighted Outputs**

Chapter 6, Concept Neurons

Real neurons have a smooth nonlinearity (Lytton, fig 6.3):

There are several different ways to describe the nonlinearity mathematically, the main difference being convenience.
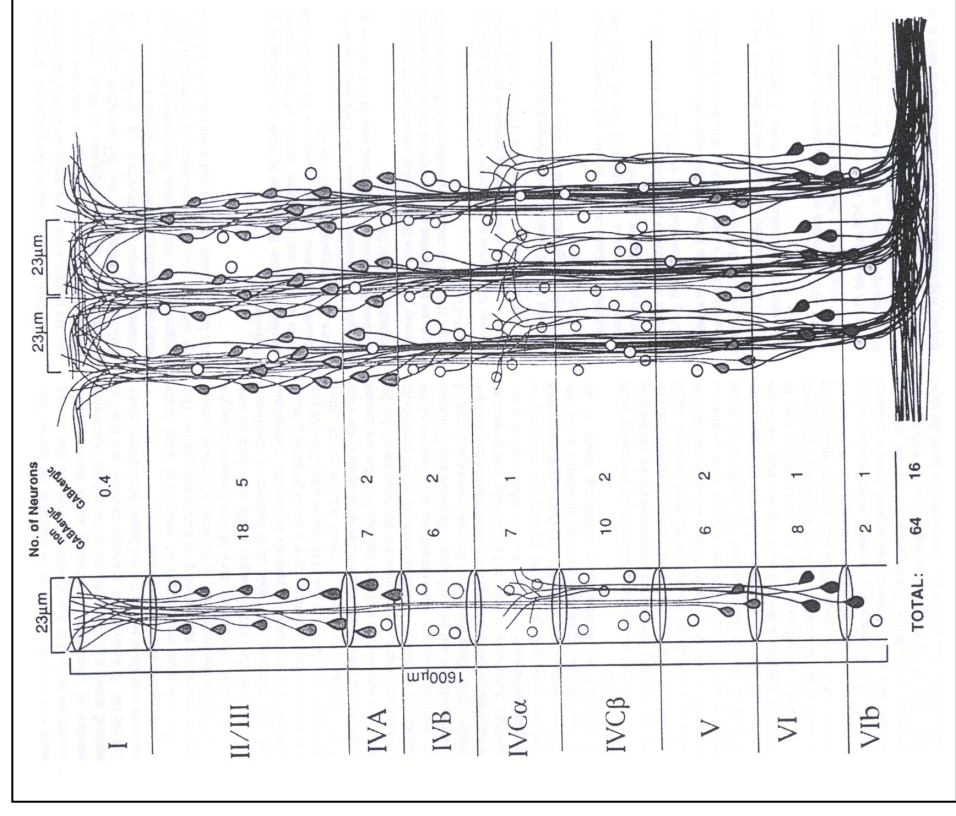
Chapter 6, Concept Neurons

Different neurons are connected in different directions in different cortical layers:

(From Kolb & Whishaw: Fundamentals of Human Neuropsychology)

Chapter 6, Concept Neurons

We should also remember that there is a columnar organization (From Mountcastle: "The columnar organization of the neocortex", Brain 1997, pp. 701-722):
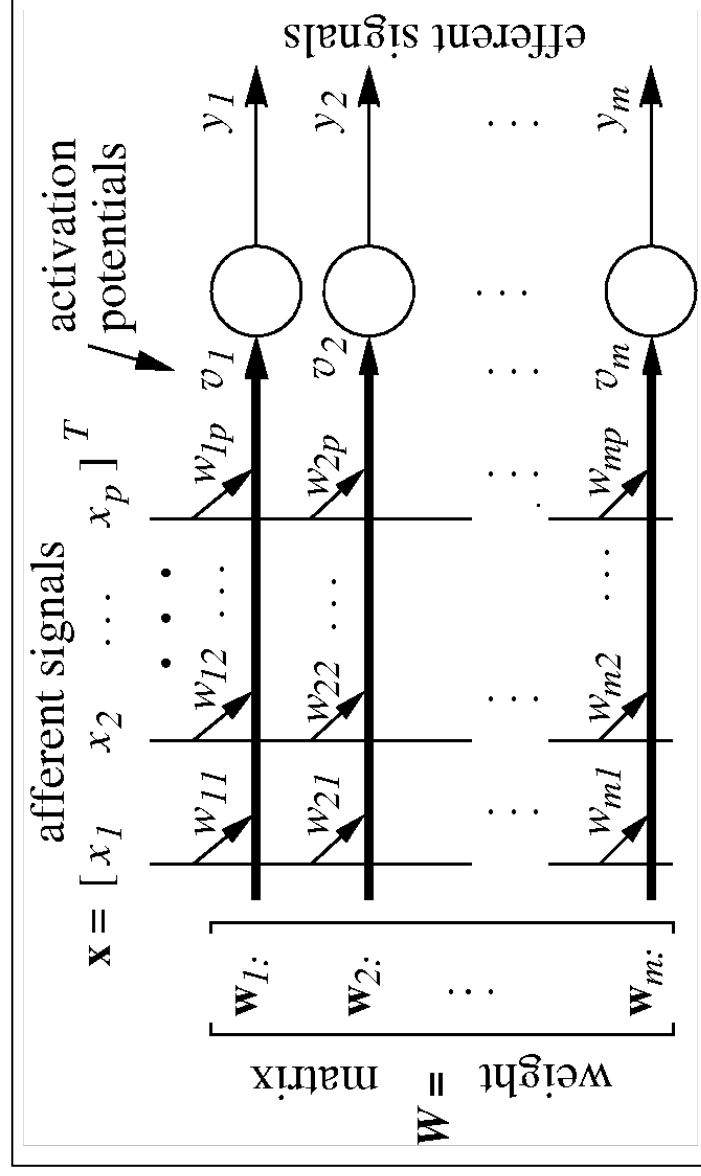
Chapter 6, Concept Neurons

In artificial neural networks we have *generic neurons*, connected in *very simplified circuits.*

Depending on the main features retained in the artificial neural networks we have main types of networks, such as *feedforward networks* and *recurrent networks*.

(in Section IV Brains we will make serious attempts to improve our models)
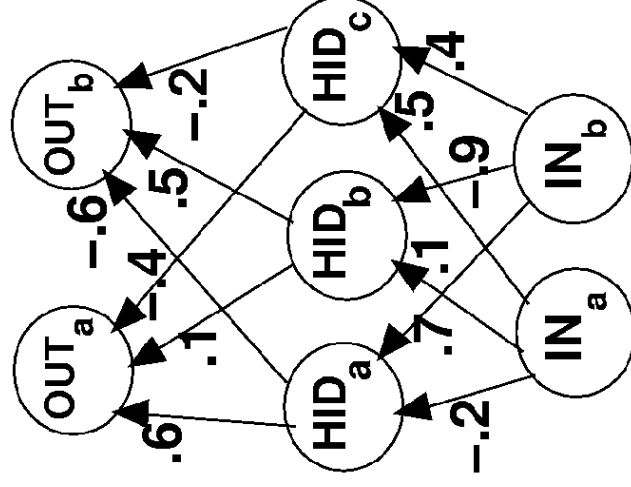
Chapter 6, Concept Neurons

A one layer feedforward network is shown below

Just one layer of neurons with no interdependence – not much of a network yet.

Chapter 6, Concept Neurons

A two layer feedforward artificial neural network (Lytton fig 6.7)
There is a hidden layer "before" the output layer of neurons.
Lytton calls this a three layer network, counting the inputs as a layer.
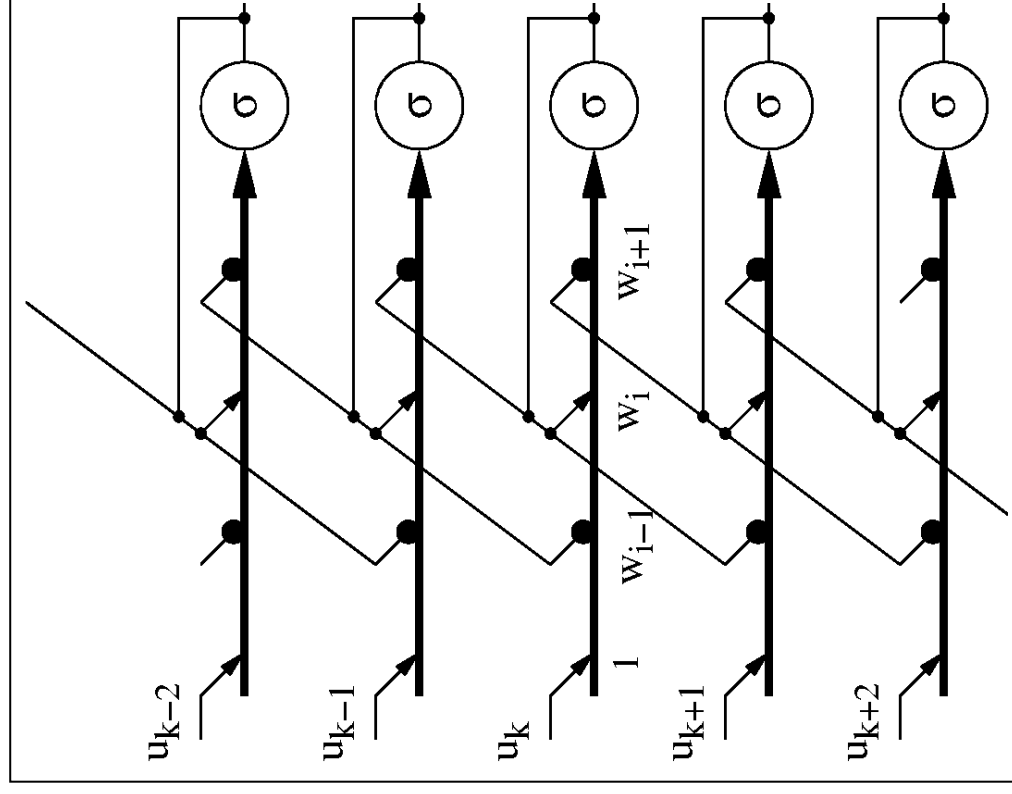
Chapter 6, Concept Neurons
A partially connected feedforward network
(from Haykin: Neural Networks A Comprehensive Foundation)
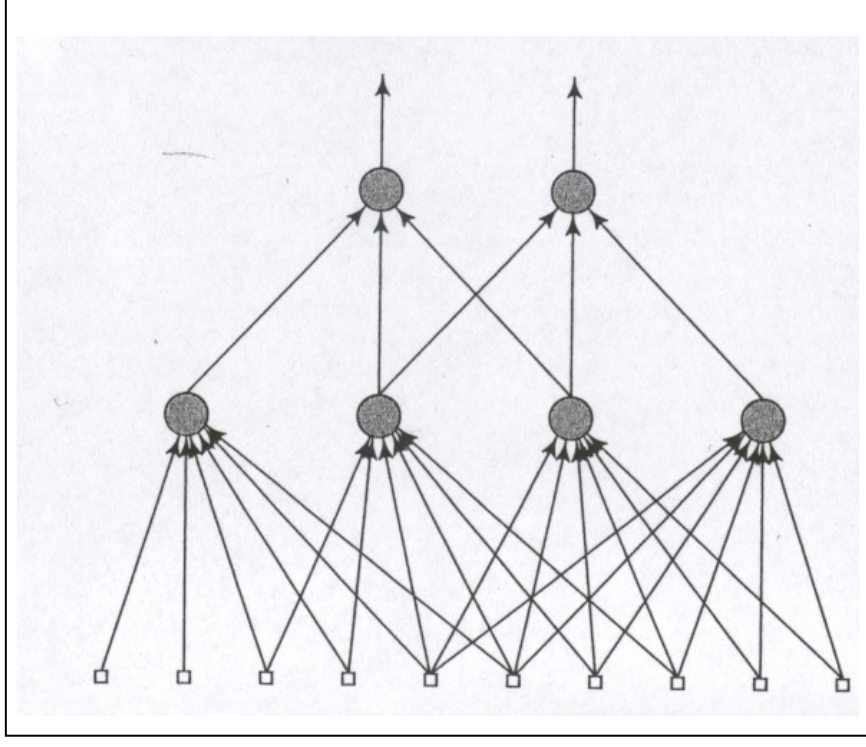
This is already a biologically more realistic model than the full connectivity models.
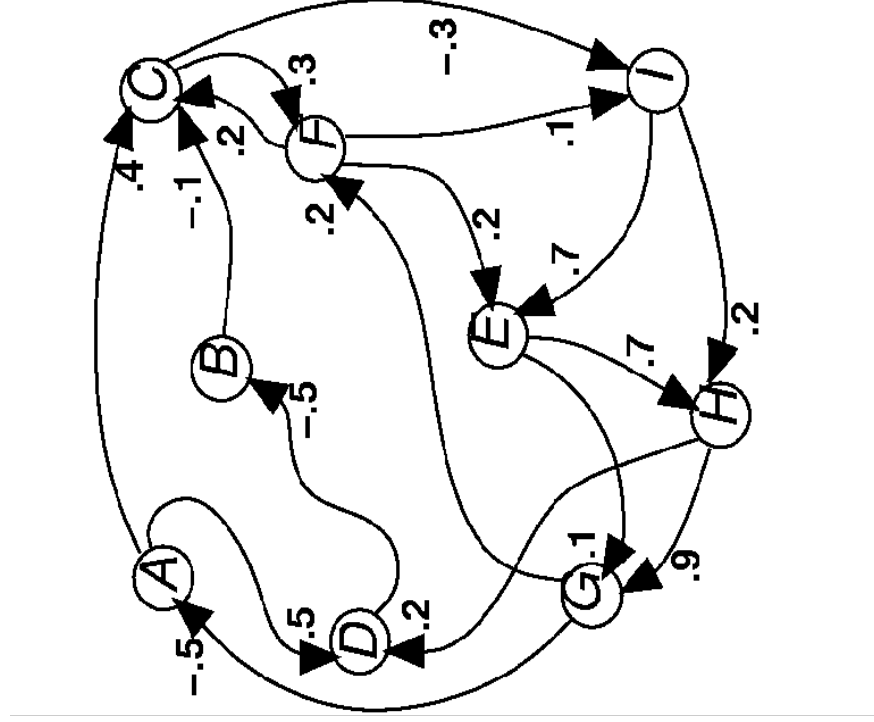
Chapter 6, Concept Neurons

A recurrent network is shown below. The efferent signals are fed back to become part of the afferent signals. There are loops in recurrent networks! The filled circles are inhibitory synapses.

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Chapter 6, Concept Neurons

A recurrent network of neurons (Lytton, fig 6.4).

There are no afferents in this version.

Chapter 6, Concept Neurons

States keep changing, at least for some time, in a recurrent network (Lytton, fig 6.5; there is a mistake in the book – unit *a* should always be 0):