Mind: Architectures, Models, Formalisms

5. One neuron, two neurons, …, *n* neurons, a mind?
Neural networks and connectionism: An intro.

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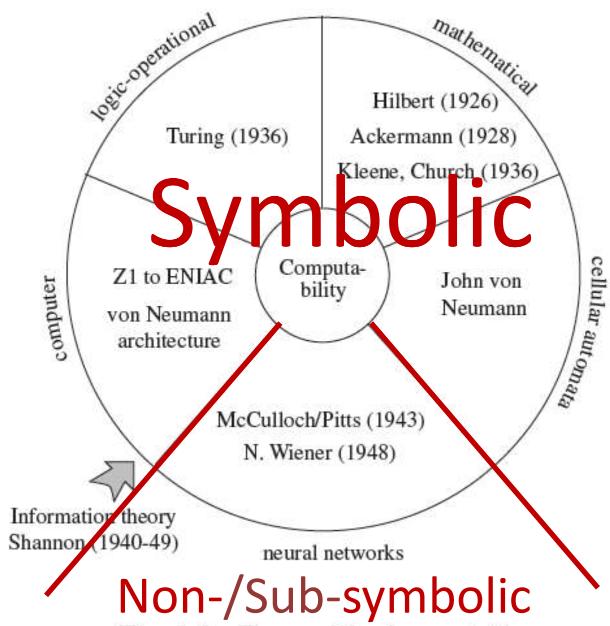
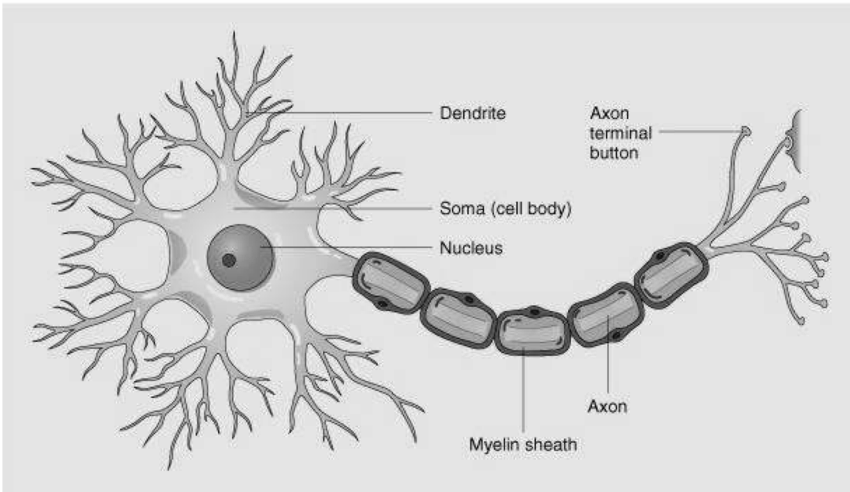


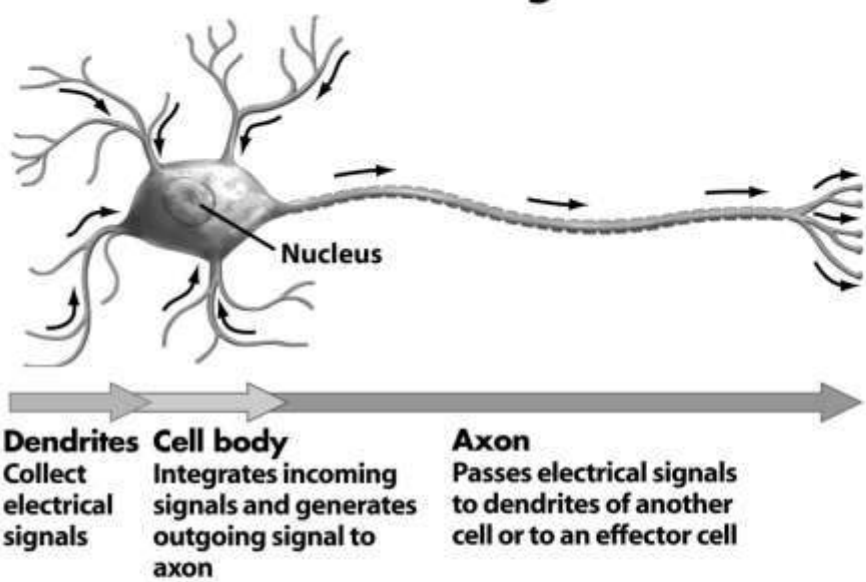
Fig. 1.1. Five models of computation

Rojas (1996), p. 7
(with additions
in red)

Neuron structure



Information flow through neurons



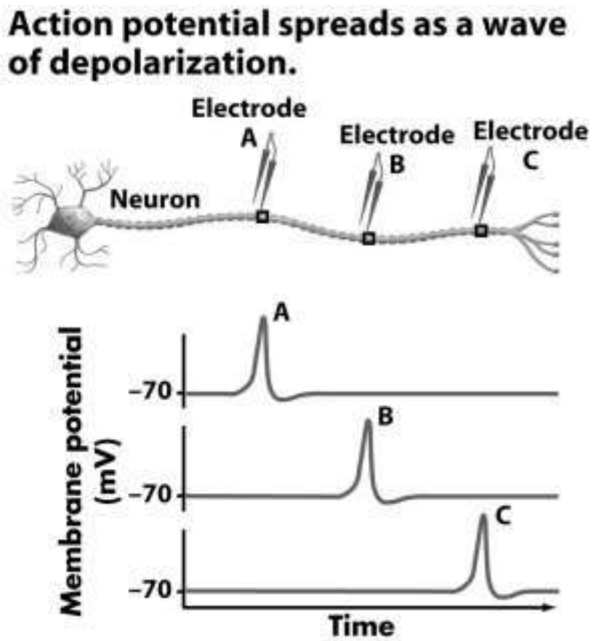


Figure 45-11b Biological Science, 2/e

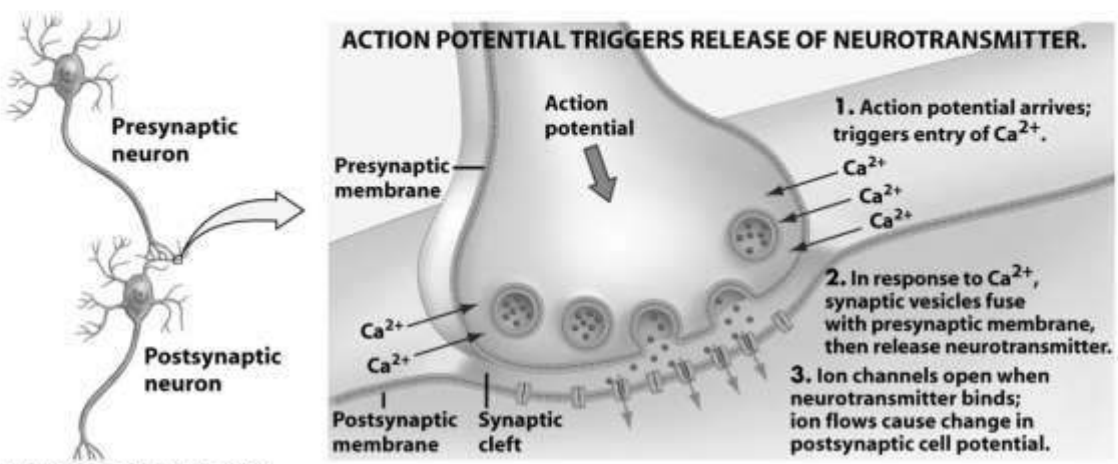


Figure 45-15 Biological Science, 2/e

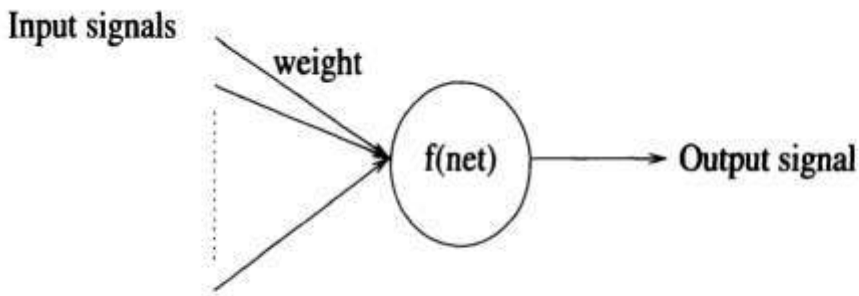


Figure 1.3: Illustration of an artificial neuron

Engelbrecht (2002), p. 8

“Biological realism”:

Input layer:
sensory neurons

Output layer:
motor neurons

Hidden layer:
interneurons

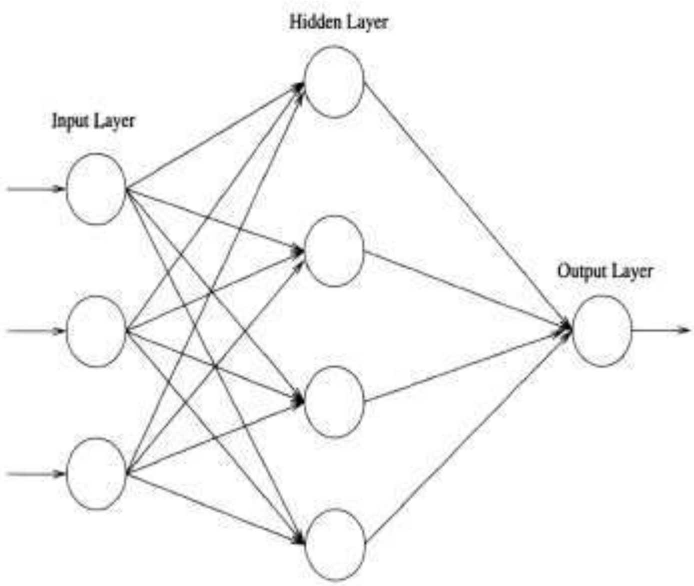


Figure 1.4: Illustration of an artificial neural network

Engelbrecht (2002), p. 8

Neural computation

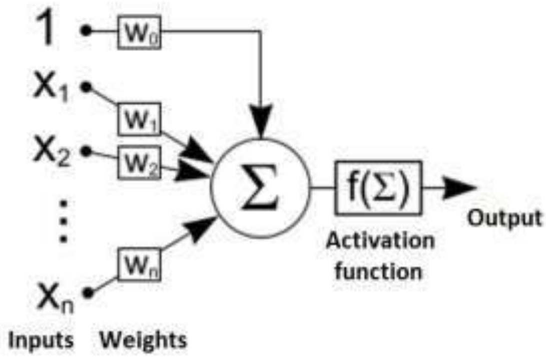
Our subject matter is computation by artificial neural networks. The adjective "neural" is used because much of the inspiration for such networks comes from neuroscience, *not* because we are concerned with networks of real neurons. Brain modelling is a different field and, though we sometimes describe biological analogies, our prime concern is with what the *artificial* networks can do, and why. It is arguable that "neural" should be purged from the vocabulary of this field … but at present it is firmly ensconced. We do however avoid most other biological terms in non-biological contexts, including "neuron" (*unit*) and "synapse" (*connection*).

Hertz et al. (1991), p. xix

Generic connectionist machine

(Harnish, 2002, p. 326)

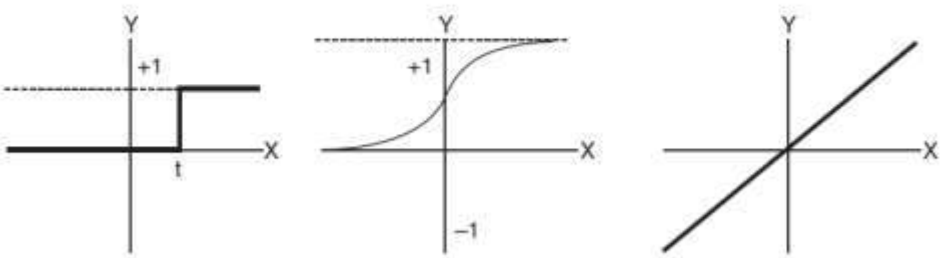
1. A network of connected computing units.
2. Each connection has a strength or weight.
3. Each unit has a rule for passing on some activation value.
4. Certain units are input units, and their (possibly joint) activation represents the input.
5. Certain units are output units, and their (possibly joint) activation represents the output.
6. Data/information is in the activation of units and the connection weights.
7. There are learning algorithms for modifying the connection weights.
8. Computation involves arithmetic operations on activation levels and connection strengths.



http://lib.bioinfo.pl/courses/view/501

Main source: Coppin, 2004

Three activation functions



(a) Step function (b) Sigmoid function (c) Linear function

$$X = \sum_{i=1}^{n} w_i x_i \qquad X_j = \sum_{i=1}^{n} x_i \cdot w_{ij} - \theta_j \qquad X = \sum_{i=1}^{n} w_i x_i$$

Activation level

$$Y = \begin{cases} +1 & for\ X > t \\ 0 & for\ X \leq t \end{cases} \qquad Y_j = \frac{1}{1 + e^{-X_j}} \qquad Y = \alpha X$$

Neural network types. Example 1:

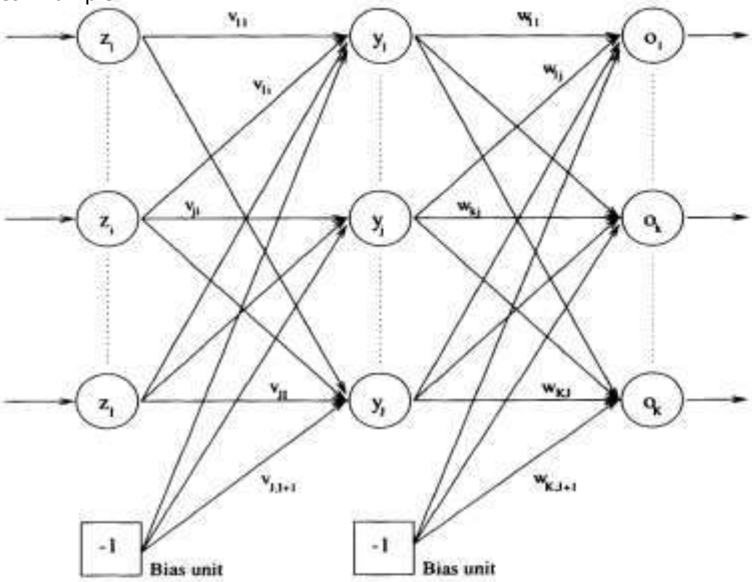


Figure 3.1: Feedforward neural network

Engelbrecht (2002), p. 28

Neural network types. Example 2:

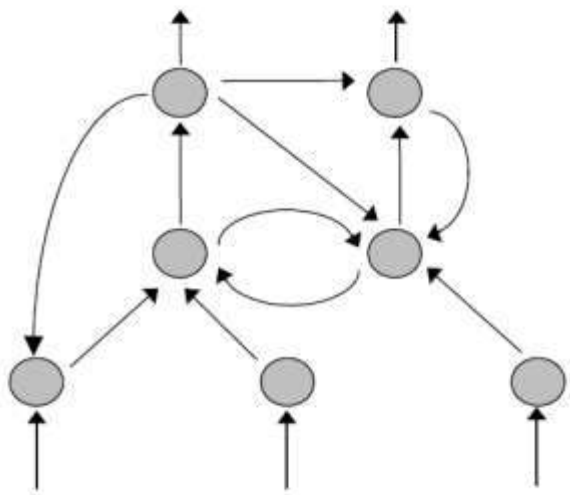


Fig. 3.5 A recurrent network

d'Avila Garcez et al. (2009) p. 30

The goal of connectionist research is to model both lower-level perceptual processes and such higher-level processes as object recognition, problem solving, planning and language understanding. There exist connectionist models of the following cognitive phenomena:

Speech perception,
Visual recognition of figures in the "Origami world",
Development of specialized feature detectors,
Amnesia,
Language parsing and generation,
Aphasia,
Discovering binary encodings,
Dynamic programming of massively parallel networks,
Acquisition of English past tense morphophonology from examples,
Tic-tac-toe play,
Inference about rooms,
Qualitative problem solving in simple electric circuits.

Smolensky (1987), p. 95-6

The connectionist computational theory of mind

(Harnish, 2002, p. 326)

1. Cognitive states are *computational relations* to *mental representations* which have content.
2. Cognitive processes (changes in cognitive states) are *computational operations* on these *mental representations*.
3. The computational architecture and representations must be connectionist.

Challenges and responses

- Fodor & Pylyshyn (1988) is a (the?) classic criticism of connectionism: while, like cognitivism or computationalism, connectionism is a representationalist theory of mind and cognition, (1) its principles and implementations do not go beyond the neural level (e.g., a neural network does not in fact 'remember' or 'learn'), and (2) its criticism of classical cognitive architectures (i.e., cognitivism) addresses inessential properties thereof. In particular, connectionism fails to explain such fundamental features of human thought and thinking as productivity and systematicity, namely because it is not committed to a symbolic level of explanation.
- Smolensky (1988) critically analyzes some common challenges to connectionism – and defends this approach by proposing a model that he sees as connectionist, the *sub-symbolic paradigm* (but which is not considered to be so by many supporters of the connectionist approach to modeling human cognition, for whom this approach is simply non-symbolic in essence).

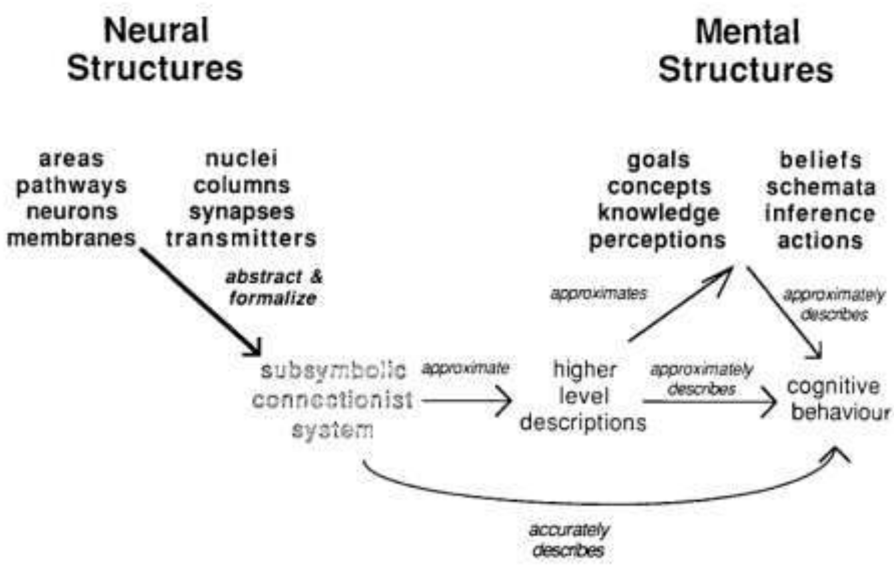


Fig. 2. Neural and mental structures in the subsymbolic paradigm.

Smolensky (1987), p. 99

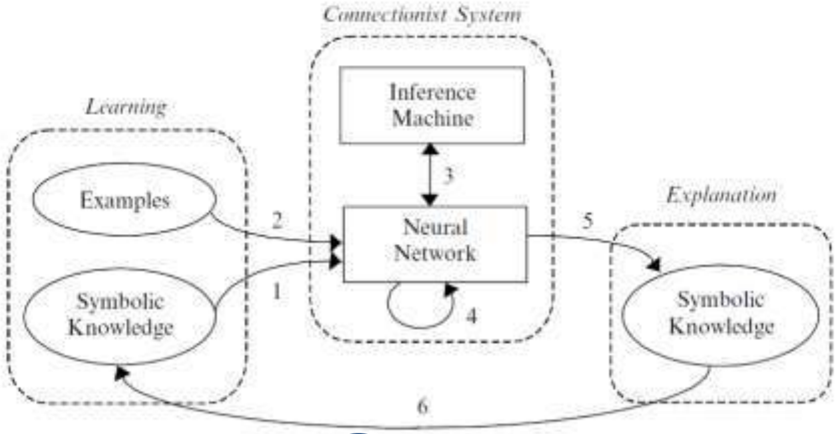


Fig. 4.2 Neural-symbolic integration

d'Avila Garcez et al. (2009), p. 37
(with additions in blue)

Main references

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