Donald O. Hebb (1949)

“The first stage of perception: growth of the assembly”
Main Ideas

1) explicit definition of the physiology of synaptic modification or Hebb synapse

2) psychology and physiology must work together to figure out how the brain controls behavior

3) Components of the proposed theory
   ▶ connectionism: repeated persistent excitation strengthen synapses
   ▶ distributed representation
   ▶ cell assemblies

4) Missing components
   ▶ no discussion of inhibition
   ▶ no precise quantitative learning rule
Cortical transmission

Past theories: *switchboard* or *field theory*.

New concept: **cell-assembly**

Cell-assemblies are self-reinforcing subsets, can act briefly as closed systems, and deliver facilitation to other systems creating a “phase sequence” or “thought process”.

Cell-assemblies are aroused by preceding assemblies or by sensory events. The concept of cell-assembly can be used to postulate a possible mechanism for the connections between perception, attention and learning.

*Deep Learning, “The first stage of perception: growth of the assembly” (Hebb, 1949)*
Perception integration: cell-assembly

- Perception depends on the structure of multiple cortical areas (e.g. beyond area 17 in the visual cortex)
- Perception invokes anatomically disorganized cells
- Two old ideas: (1) association of cells which are repeatedly active together and (2) lowered synaptic resistance.
- Growth and synaptic activity makes synapses “more easily traversed”
- Learning involves both fast and slow processes: “dual trace mechanism”
Conduction in the visual cortex

Area 17 to Area 18, 19, 20
- convergence and spread of excitation
  (where excitation $\sim$ connection)
- diffused transmission beyond area 17.
  Excitation patterns remain specific to the stimulus.

Deep Learning, “The first stage of perception: growth of the assembly” (Hebb, 1949)
Sample circuits

Diffused transmission in the visual cortex

Figure 7  Illustrating convergence of cells in Brodmann's area 17 upon cells in area 18, these cells in turn leading to other areas. A, B, C, three grossly distinct regions in area 17; D, E, F, G, H, cells in area 18. See text.
Sample circuits

The functional link between A and B is strengthened through persistent stimulation.

Figure 8  Cells A and B lie in a region of area 17 (shown by hatching) which is massively excited by an afferent stimulation. C is a cell in area 18 which leads back into 17. E is in area 17 but lies outside the region of activity. See text.
Sample circuits

B, D and X form a closed circuit.

Figure 9  A, B, and C are cells in area 18 which are excited by converging fibers (not shown) leading from a specific pattern of activity in area 17. D, E, and X are, among the many cells with which A, B, and C have connections, ones which would contribute to an integration of their activity. See text.
Sample circuits

Assembly for a long-lasting reverberation

**Figure 10** Arrows represent a simple “assembly” of neural pathways or open multiple chains firing according to the numbers on each (the pathway “1, 4” fires first and fourth, and so on), illustrating the possibility of an “alternating” reverberation which would not extinguish as readily as that in a simple closed circuit.
Principles of cell-assembly

- cell-assemblies consist of closed circuits of “assembled” cells
- reverberation in simple closed circuits is fast but can create complex behavior in the larger system
- the proposed circuits are possible under the assumption that the brain contains a large number of fibers distributed at random
Implications for psychology

- integration of perception is a long process
- association between two perceptions is possible only after each one is independently organized
- there may be considerable variation in the ease of association
- there may be significant differences in the properties of perception at various stages of integration (growth; learning)