CHAPTER 5:
SIMPLE NERVOUS SYSTEMS
AND BEHAVIOR
Life on Earth

Choanoflagellates
Probable animal ancestors, unicellular, aggregate in groups, feed on bacteria, similar to some cells in sponges.
Invertebrates with no nervous system

Invertebrates with nervous system

Vertebrates
Simple nervous systems: Invertebrates

Gangliar organization of the CNS of invertebrates with bilateral symmetry (notice the ventral position).
Tardigrades

https://www.youtube.com/watch?v=IxndOd3kmSs
Duration: 4:09 min
Octopus intelligence

https://www.youtube.com/watch?v=Z0iUIWnon9Y
Duration: 1:33 min
The neuron

Hippocampal neuron stained for spectrin (red) and tubulin (green).

**Myelin**: evolved independently in vertebrates and other phyla, apparently several times (present in earthworms and some shrimp species). Most invertebrates lack myelin.
Neuron # 1

Vescicle with neurotransmitter

Extracellular compartment (ions, enzymes, etc.)

Receptor

Synapse

Neuron # 2
How does the pain you experience when you burn your hand result so quickly in an action by your muscles?
Neurons: Synaptic transmission

Video

Synaptic Transmission

From Neuroscience, Fourth Edition.
Storyboard and animation by Sumanas, Inc.
Sample version. Not for distribution.

https://www.youtube.com/watch?v=kFV9wpqj-8
Duration: 3:37 min
*Neural nets.

*No differentiation between CNS-PNS.

*Neurons have familiar properties.
Jellyfish

https://www.youtube.com/watch?v=Q2zZ2S5esu8
Duration: 9 s
Functional properties of cnidarian neurons

Graded potentials

Action potential

Presynaptic

Postsynaptic

Echo

Jellyfish
Basic behaviors

• Simple-system approach
• Reflexes
• Modal action patterns
• Behavioral plasticity (learning)
Animal evolution: a simplified view

- Sponges
- Cnidarians
- Planarians
- Arthropods
- Mollusks
- Vertebrates

- Multicellular animals, no neurons
- Neurons, diffuse nervous systems
- Central nervous systems (CNS)
To study the neural basis of behavior, one approach is to select a simple behavior and a simple nervous system.

Simple behavior:
• Reflexes
• Modal action patterns
• Habituation
• Sensitization
Aplysia californica

http://www.youtube.com/watch?v=Q1KI30JmemU
Duration: 17 s
Simple nervous systems: Mollusks

- Few neurons
- Large neurons
- Stable locations across animals
- Identifiable

*Aplysia californica* (sea hare)
Basic behaviors

• Simple-system approach
  • Reflexes
  • Modal action patterns
  • Behavioral plasticity (learning)
A unit of behavior that includes:

• An input (stimulus),

• Some degree of processing in the CNS (monosynaptic, polysynaptic), and

• An output (simple response or secretion).
Gill-withdrawal reflex of *Aplysia*

Figure 20.4
The gill-withdrawal reflex in *Aplysia*.
Gill-withdrawal reflex of *Aplysia*

- Stimulating and recording electrodes
- Abdominal ganglion
- Siphon nerve
- Gill
- Genital nerve
- Pericardial nerve
- Branchial nerve
- Water pik
- Siphon
Basic behaviors

- Simple-system approach
- Reflexes
- Modal action patterns
- Behavioral plasticity (learning)
Modal action patterns

Sequentially organized, species-typical behaviors that once activated develop in a ballistic manner.

Stimulus: jet of salty water simulating a predator (starfish)

Dorso-ventral contractions (escape response)

Animal lands at a distance from previous location

MAP in *Tritonia*
Escape MAP in *Tritonia*
Basic behaviors

• Simple-system approach
• Reflexes
• Modal action patterns
• Behavioral plasticity (learning)
A tentative classification of learning phenomena

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<th>Learning Phenomena</th>
<th>General</th>
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<td>• Human language</td>
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<td>• Song learning</td>
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- Classical conditioning
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- Sensitization
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Properties of habituation

![Graph showing habituation trials with different conditions](image)

- **Habituation Trials**: 1 to 9
- **ISI = 60 s** and **ISI = 10 s**
- **Strong** and **Weak** signals
- **600 Hz**, **200 Hz**, **400 Hz**
- **Resting period**

The graphs illustrate the response strength over time for different conditions and intervals, demonstrating the habituation process.
Habituation of the Galvanic skin response in humans
Aplysia's siphon retraction reflex and learning

https://www.youtube.com/watch?v=yLa-cXg8BwM
Duration: 4:01 min
Habituation in *Aplysia*
Habituation of the gill-withdrawal reflex in *Aplysia* is caused by a decrease in calcium influx into sensory neuron, which causes a reduction in neurotransmitter release onto motor neuron, thus decreasing the motor response (gill contraction).
Dishabituation and sensitization in *Aplysia*

**Short-term sensitization**

**Long-term sensitization**
Short-term sensitization and dishabituation in *Aplysia*: Mechanisms

↓$K^+$ outflux: short-term sensitization (spike broadening)

↑$Ca^{++}$ influx: dishabituation (increased excitability)
Short-term habituation and dishabituation in *Aplysia*: A cellular model
A conversation with Eric Kandel

http://www.youtube.com/watch?v=rHx32Erpyfo
Duration: up to 16:30 min
A conversation with Eric Kandel: Summary

- In the 1950s there was a family of competing ideas about how memories could be stored: diffused storage, glial cells, synapses critical.

- Explicit or declarative memory: the recall of information about people, places, and objects, and it requires the medial temporal lobe and the hippocampus.

- Implicit or procedural memory: perceptual/motor skills, habits, including classical and operant conditioning, habituation, and sensitization.

- Aplysia: a simple animal, simple nervous system, and simple behavior, a reduced form of a human brain.

- Short-term vs. long-term memory: preexisting connections and proteins vs. gene expression, new protein synthesis, and new connections.

- Only those synapses that are active are strengthened.

- Experience can alter whether a gene is turned on or off in a neuron.

- Brain representations depend on experience.

- Survival requires the ability to modify responses through learning.
Scientists have transplanted memory from one snail to another. So, what does it mean for humans?

By AJ Willingham, CNN
Updated 11:12 AM ET, Thu May 17, 2018
Memory transfer in *Aplysia*?

- LTM is believed to be encoded in synaptic strength.
- Alternatively, LTM could be encoded by epigenetic changes.
- Thus, RNA from a trained animal might produce learning-like behavioral change in an untrained animal.
- Memory for long-term sensitization in *Aplysia* was transferred by injecting RNA from sensitized into naïve animals.
- Sensory neuron hyperexcitability was reproduced by exposing sensory neurons in vitro to RNA from trained animals.
- The results support a nonsynaptic, epigenetic model of memory storage in *Aplysia*. 
Morphological changes in long-term habituation and sensitization

Long-term habituation

Long-term sensitization

Normal
Evolution of neural plasticity

- **Lower invertebrates**: Plasticity: peripheral
  - Body surface
  - Effector

- **Higher invertebrates**: Plasticity: peripheral & central
  - Body surface
  - Effector

- **Vertebrates**: Plasticity: only in the CNS
  - Body surface
  - Effector

- △ Excitatory
- ▲ Plastic