

# Neuroscience: The Brain and Cognition

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- ▶ The study of the physical realization of information processes in animal and human nervous systems.
- ▶ Based on Chapter 7 of **Stillings et al.: Cognitive Science, MIT Press (1989)**.
- ▶ Why should we be interested?
  - ▷ Fascinating.
  - ▷ Test theories developed in cognitive psychology and linguistics.
  - ▷ Information processes that a system can carry out efficiently are strongly constrained by the available physical hardware.
  - ▷ Practical applications.
- ▶ Major areas:
  - ▷ Neurophysiology: the study of the functions of the nervous system.
  - ▷ Neuroanatomy: the study of the structure of the nervous system.
  - ▷ Neuropsychology: the study of the relation between neural and psychological functioning.

# Structure and Functions of the Nervous Systems

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- ▶ **Human brain:  $10^{12}$  neurons with approx.  $10^3$  connections each.**
- ▶ **How are they coordinated?**
- ▶ **Compartmentalization.**
- ▶ **Topographic organization:**
  - ▷ **In the somatosensory cortex (Penfield).**
  - ▷ **In the visual cortex: retinotopic maps.**
  - ▷ **In the motor cortex.**
  - ▷ **In the auditory cortex: tonotopically organized.**
- ▶ **Low-level orderings seem to be represented analogously.**
- ▶ **What about higher-level orderings?**

# The Gross Structure of the Nervous System

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- ▶ How are the various parts of the brain connected to their corresponding peripheral structures?
- ▶ Central nervous system (CNS): brain and spinal cord.
- ▶ Peripheral nervous system: all other nerve fibers.
- ▶ Receptors (photo-, chemo-, mechano-, etc.) deliver information to the CNS through afferent fibers.
- ▶ The CNS delivers information to muscles and glands through efferent fibers.

# The Neuron

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- ▶ Cell body, dendrites, soma.
- ▶ Unidirectionality of signalling.
- ▶ Dendrites: spacial vs. temporal summation.
- ▶ Axon hillock: if the arriving signal is strong enough the action potential is propagated along the axon.
  - ▷ 30 m per sec; with myelin cover up to 120 m per sec.
  - ▷ Action potential seems to be independent of type of receptor.
- ▶ The difference in perception is not based on the form of the signals but on the patterns of connectivity of the neurons.

# The Synapse

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- ▶ **Sir Charles Sherrington hypothesized a gap between nerve fibers: the synapse.**
- ▶ **Communication across synapses is by transmission of chemicals, the neurotransmitters.**
- ▶ **There are excitatory and inhibitory synapses.**
- ▶ **There are more than 50 different neurotransmitters.**
- ▶ **Drugs may modify neurotransmitter activities:**
  - ▷ **Nicotine facilitates the transmission of acetylcholine.**
  - ▷ **Valium R promotes the transmission of gamma-aminobutyric acid.**
  - ▷ **LSD blocks the transmission of serotonin and chlorpromazine.**

# Patterns of Connectivity

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- ▶ **How does the organization of the nervous system allow for the orderliness of experience?**
  - ▷ **Patterns of connectivity between neurons.**
  - ▷ **Local communication.**
  - ▷ **Directed signalling.**
  - ▷ **Simple computations:**  
excitatory and inhibitory connections, spacial and temporal summation.
- ▶ **There is no evidence for a central controller!**
- ▶ **There is no evidence for complex messages send along an axon!**
- ▶ **But we still don't know much about the nervous system.**

# The Control of Simple Actions

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- ▶ **Feedback loops.**
- ▶ **Reciprocal inhibition.**
- ▶ **Feedforward systems.**
- ▶ **Modularity.**
- ▶ **Directional tuning curves.**
- ▶ **Distributed representation.**
- ▶ **Outputs of the neurons are combined.**

# Vision

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- ▶ Lateral inhibition (**Ratliff & Hardline 1959**)
- ▶ Orientation-dependent line detectors for particular parts of the visual field (**Hubel & Wiesel**).
- ▶ Convergent connections.
- ▶ Redundancies.
- ▶ Simple vs. complex cells.
- ▶ Hierarchical and cooperative processing.
- ▶ Is there a “grandmother” cell?

# Plasticity, Learning and Memory

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- ▶ **Adjustment according to experience.**
- ▶ **Synaptic basis for learning.**
- ▶ **Short-term and long-term memory.**