

Interdisziplinäres Projekt

Memory

Nadine Dreidoppel

Anna Gromova

Ingrid Kost

Annika Orland

Anika Röhrig

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Have you ever found yourself running late, desperately looking for misplaced car keys? Did you ever stride purposefully into a room, only to forget why you're there?



But don't be worried, these relatively minor memory lapses are perfectly normal.



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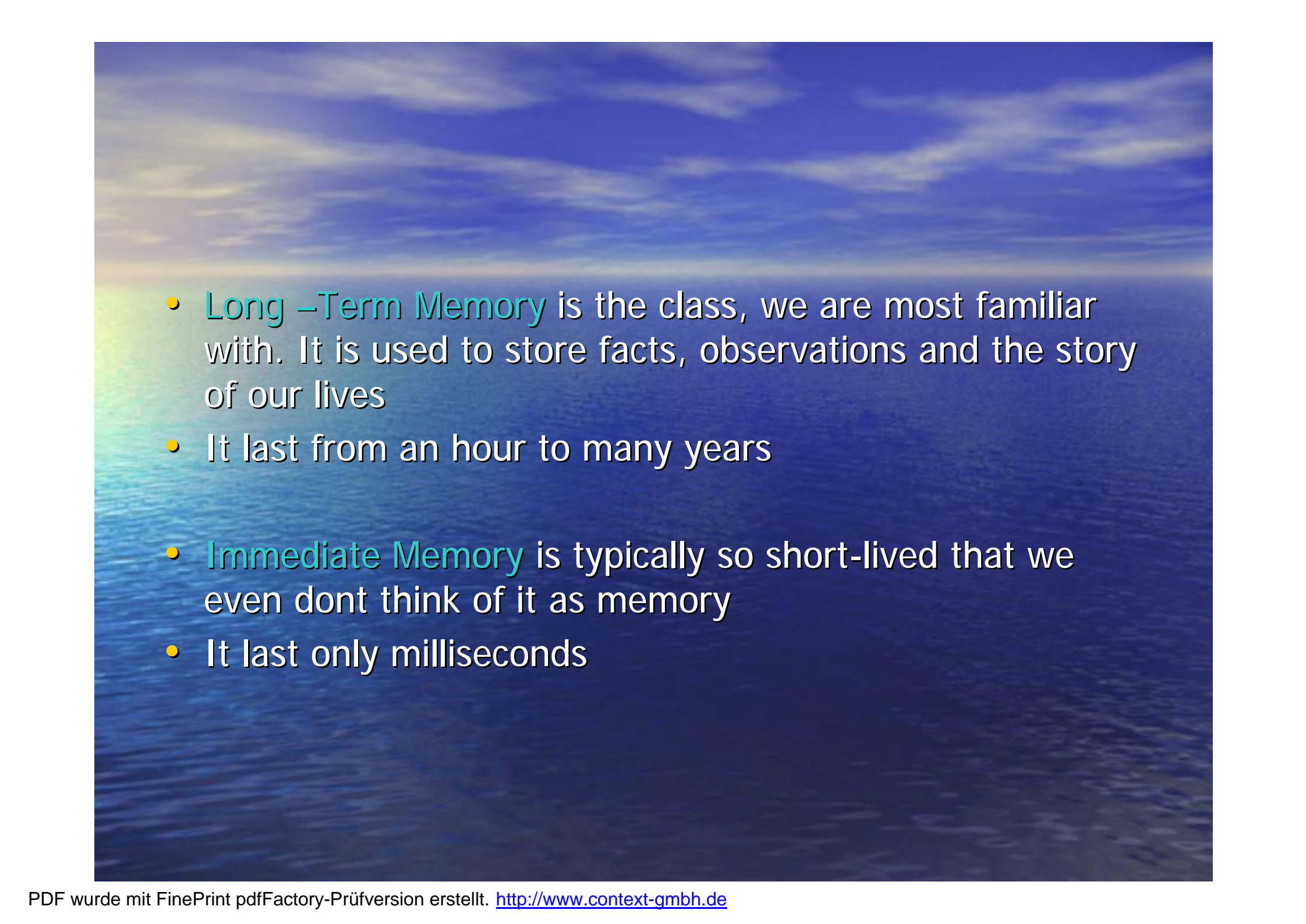
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Memory, an short overview

- *Memory* is the retention of, and ability to recall, information, personal experiences, and procedures (skills and habits).
- There are three main subdivisions of memory.
- Each of which is processed in a different area of the brain.
- *Working memory* happens at the front of the brain, in the prefrontal cortex.
- This type of memory coordinates sights, sounds 🎵 and feelings, so one can respond to events as they happen.



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- **Long –Term Memory** is the class, we are most familiar with. It is used to store facts, observations and the story of our lives
 - It last from an hour to many years
 - **Immediate Memory** is typically so short-lived that we even dont think of it as memory
 - It last only milliseconds

Nondeclarative and Declarative Memory

- Skills like catching a baseball or riding a bicycle are called **nondeclarative memory**
- **Declarative memories**, on the other hand are memories of facts and events that we can consciously recall and describe verbally

How memories are made

- An event starts out in **immediate memory**, spread out in various modality-specific regions of the brain. Reinforcement through attention causes the relationship between sight sound, and context to consolidate into **working memory** in the prefrontal lobe. Further reinforcement through practice causes more consolidation, and the most critical relationships in the event (the name, the face, and the context) are tied together in the hippocampus. From there, the memory relationship is probably stored diffusely across the **cerebral cortex**, but research on the actual location of memory relationships is still inconclusive.

In short form:

Our memories are formed through associations. When we experience an event, our brains tie the sights, smells, sounds 🎵🎵 🎵🎵 🎵🎵, and own impressions together into a relationship,



That relationship itself is the the memory of the event

From a practical perspective

- We can remember something best, if we learn it in a context that we understand, or if it is emotionally important to us.
- The human brain is not good at remembering long lists of unrelated numbers or nonsense words



The Brain



Myths and Mysteries about the brain



- A common myth is, that we use only 10% of our

brain 😊

▶ But: Never will you see activity in just 10 % of the brain



- *Memory* is the retention of, and ability to recall, information, personal experiences, and procedures (skills and habits).
- Human memory exists in the brain.
- This is an organ, which works through an electro-chemical process.



- There are about 10^{11} active brain cells or **neurons** in a normal human brain.
- About 10^{10} of these are in the **cerebral cortex**
- The brain is divided into different hemispheres.
- Every hemisphere has a specialized function.



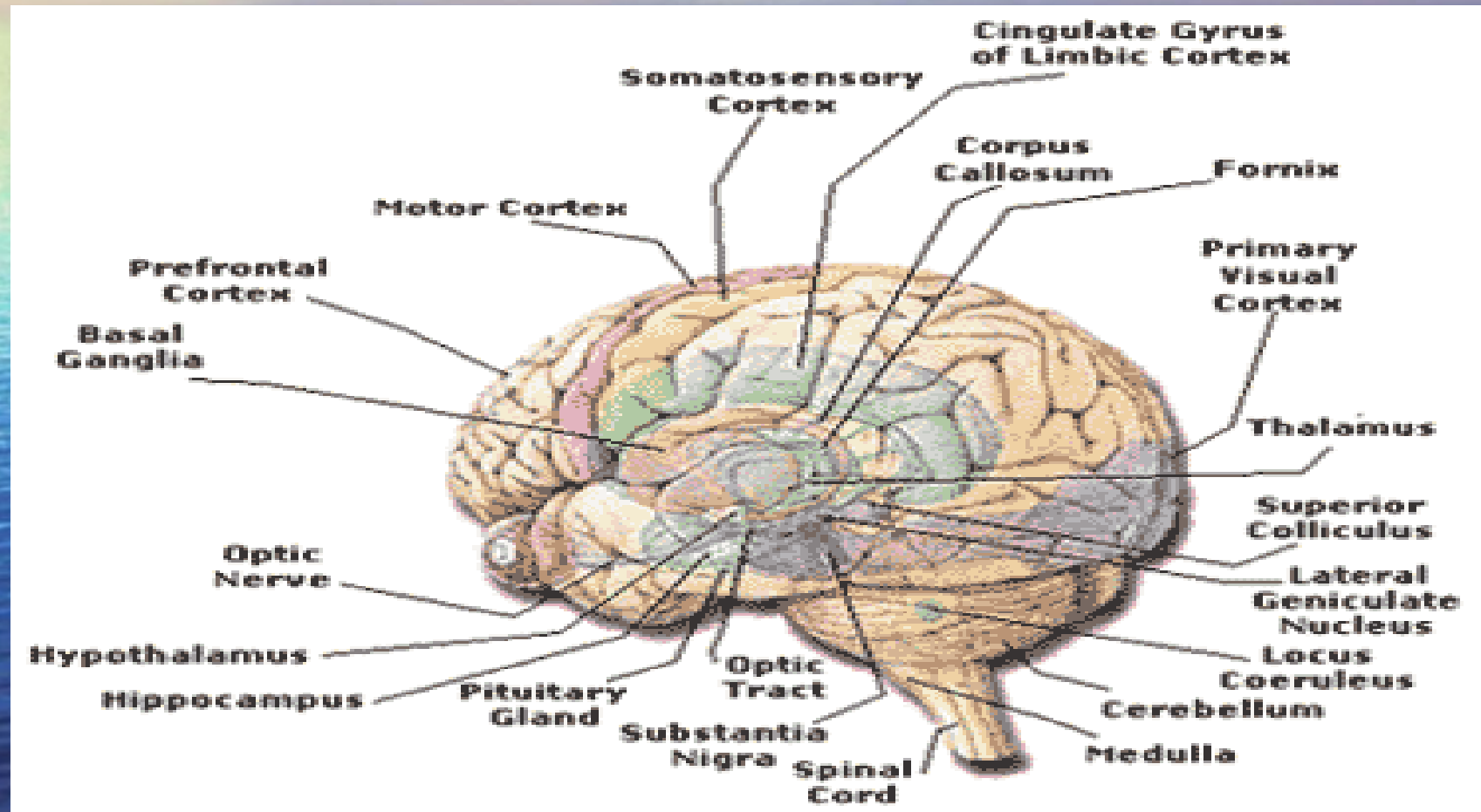


- The cortex is the outer layer of the brain.
- Though it is only a few millimeters thick, the deep folds of the cortex contain 70% of a person's one hundred billion brain cells.



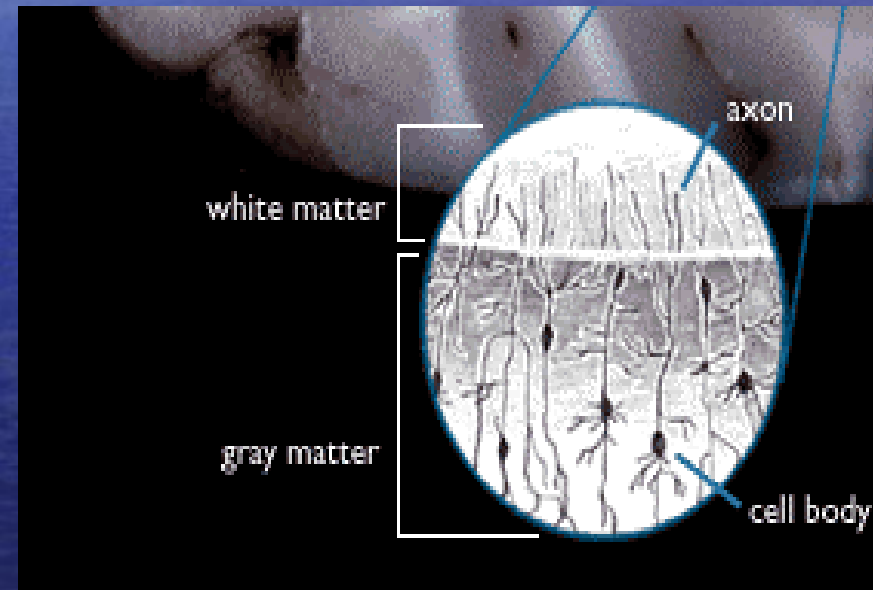
- The cells of the cortex are responsible for the highest level of cognition which includes all thought and memory.
- Humans have a larger cortex than other animals.

Brain Structures





- The dark coloured top of the cortex is called **grey matter**. It gets its colour from the dark nuclei of the brain's cell bodies.
- The inner lighter layer is called **white matter**. It is made up of the long white extensions, called axons, which are running from the cell bodies.





- The axons of each brain cell reaches out through the brain to make connections with other brain cells.
- It is through these connections that billions of brain cells relay information to billions of other brain cells , creating a communication network that makes thought possible.

Neurons and Glia cells



Neurons and Glia

- Neurons are the base of memory
- nine times as much glia cells than neurons.
- More than half of the cell mass contains of glia cells!

Neurons and Glia

- Neurons and glia are in contact with each other
- glia cells communicate with each other!
- There are two networks in the brain:
 - the neural network and the
 - Glial network

Neurons and Glia

- The glia cells influence synaptical strength of the neural network!.
- Neurons act through the electrical pathway
- Glia act through the chemical pathway

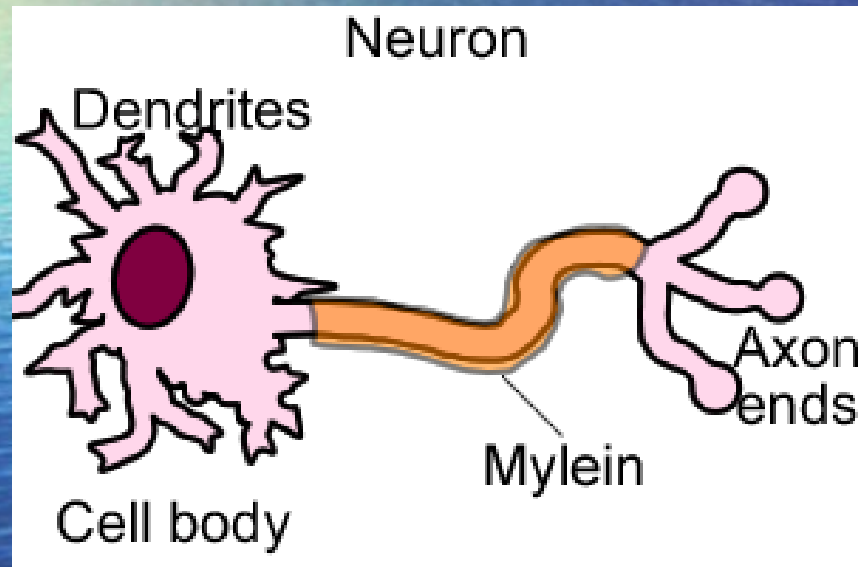
Neurons and Glia

- Types of neurons:
 - Receptor cells - receive information from the environment.
 - Sensory neurons - messages travel from the receptor cells through the sensory neurons to the spinal cord and brain.
 - Interneurons - connect sensory neurons to the motor neurons.

Neurons and Glia

- Motor neurons - messages travel from the brain and spinal cord through motor neurons to the muscles and glands
- Effector cells - cells stimulated by the motor neurons.

Neurons and Glia



- The **Cell Body**, the largest part of a cell, general parts, nucleus.
- **Axons**, contact target structures
- **Dendrites** information from the axons of other neurons

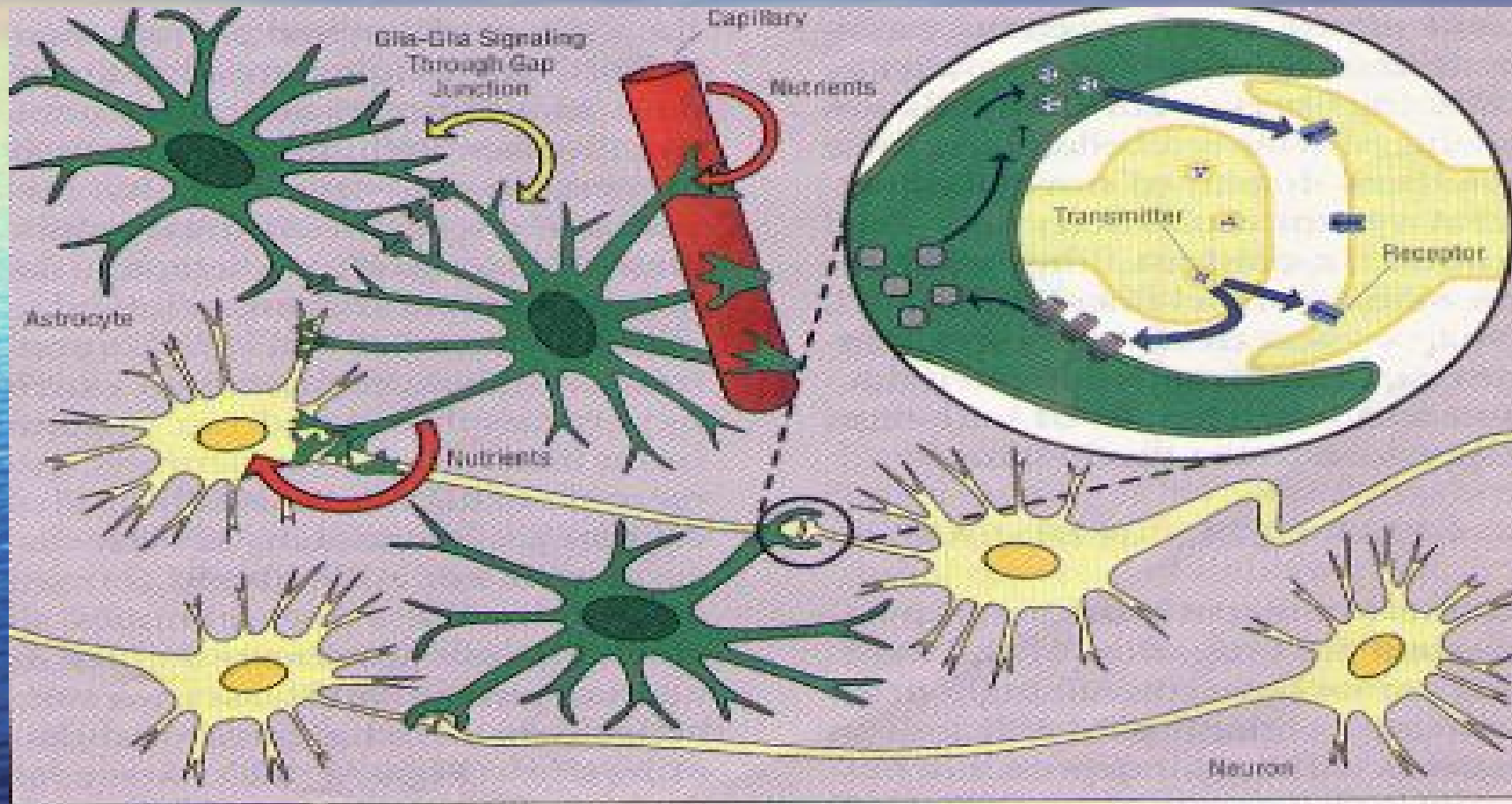
Neurons and Glia

- Astrocytes, mechanical support and maintain the ionic environment.
- Oligodendrocytes, specialised glial cells produce myelin.
- Microglia, specialised macrophages.

Neurons and Glia

- Nerves are triggered through neurotransmitters.
- The nerves send and receive various neurotransmitters as the nerve impulse travels the length of the neuron.
Neurotransmitters are released by the axonal end and bind to receptors on the Dendrite end of the neuron.

Electrical network



GLIA

- Experiment with Calcium.
- When the neuron gets an electrical stimulus calcium gets free and flows into it.
- This can be proved because they begin to “glow”
- The amazing thing was that after about 15 sec. the glia cells also began to “glow”

GLIA

- So glia cells react to electrical impulses without generating any action potentials!
- But why?
- It was found out that the neurons pass on a signal and the glias take it up and pass it on to all other relevant glia.
- This happens without contact to each other.

GLIA

- Glia cells get those impulses from ATP.
- When an electrical impulse stimulates the neuron it releases ATP.
- Glia cells take it up and pass on the information they received.

GLIA

- Experiment with rats:
- Glia cells do influence the production of new synapses.
- They stimulate impulses from neurons
- They define – even over a long distance – the strength of synapses
- They coordinate neuron population
- And thus “regulate” and stimulate memory and plasticity!

GLIA

- Would you compare neurons and glia with phones, then neurons would be normal ones and glia would be handys.
- Normal phones need a cable to send and receive information.
- Glia send information into the open environment – over long distances.

GLIA

- Another proof that glia cells are needed for memory is the fact that the number of glia rise with steps in evolution.
- The higher an organism is – according to evolution, the more glia cells there will be!
- From mammals to humans there is a huge rise in numbers!

GLIA

- By the way...
- Parts of the brain of Albert Einstein were examined according to the amount of neurons and glia...
- Compared to "normal" human beings, he had an enormous high amount of glia cells!

Aplysia-sea slug



Genus Opithobranchia

Hermaphrodites: both partners fertilize each other with their sperm during mating

Feeds on delicate seaweeds

Aplysia - sea slug



- Aplysia snail is a giant marine snail
- About 5 inches long
- Dirty yellowish colour veined with purple
- When disturbed it emits a very fine purplish-red fluid
- (slug is less complex)

Large neurons

Many of the nerve cells are gigantic and uniquely identifiable

Only a few hundred neurons

Memory

- Short-Term Memory

involves an increase in efficiency with which nerve impulses pass across synapses

- Long-Term Memory

involves formation of new synaptic connections

Sensitization:

- Definition:

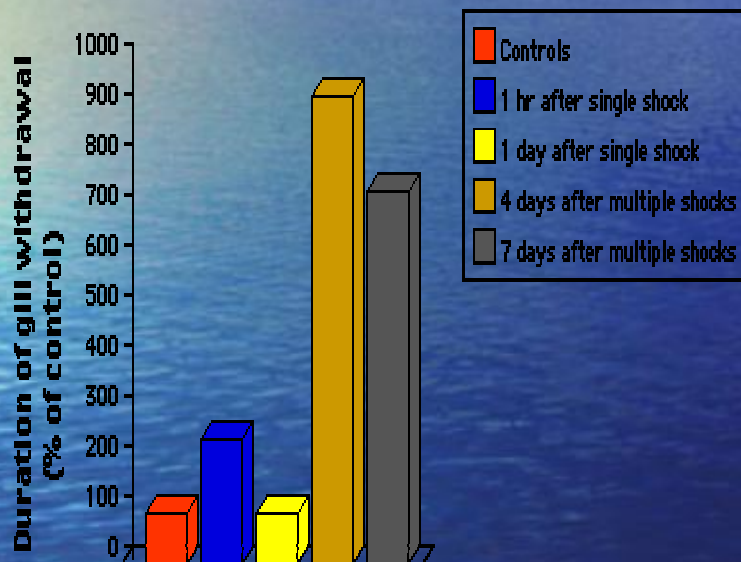
It is an increase in the response to an innocuous stimulus when that stimulus occurs after a punishing stimulus

Sensitization:



- Gently touch of siphon, aplysia withdraws its gill for a brief period
- If preceded by an electrical shock to its tail, the same gentle touch to the siphon will elicit a longer period of withdrawal.

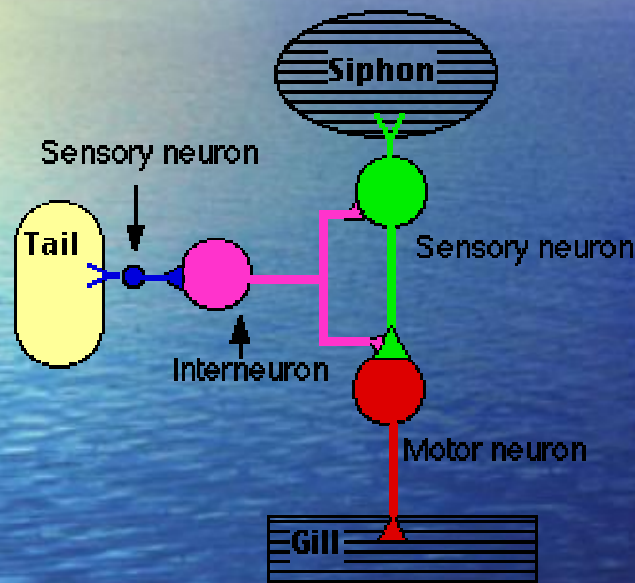
Sensitization:



- Short-Term Memory
Response to a single shock (blue bar) dies out after one hour and returns to baseline after a day (yellow).
- Long-Term Memory
After multiple shocks after several days the response is much larger and is retained longer (tan and brown bars).

Sensitization:

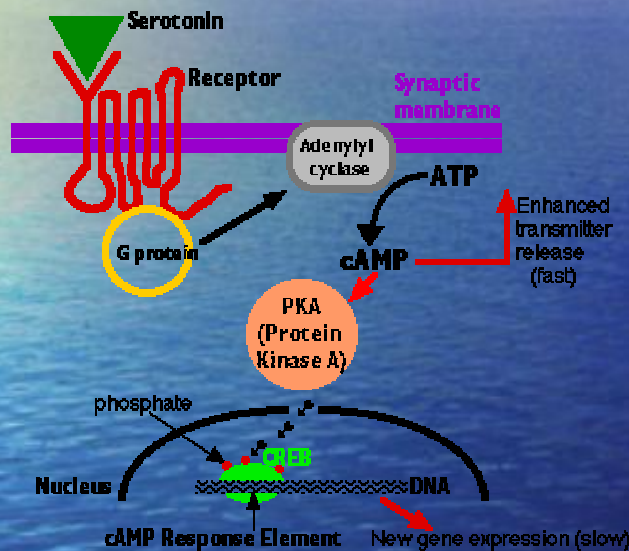
- Withdrawal of the gill requires a two-neuron connection: a sensory neuron (picks up the touch stimulus at the siphon and transmits through a synapse to a motor neuron (transmits) to muscle of the gill.



Sensitization to a noxious stimulus delivered to the tail requires: a sensory neuron (blue), that picks up the stimulus from the tail connecting to interneurons, that terminate on the sensory neuron in the siphon-gill pathway.

Facilitation:

- Short-term Facilitation:
a single shock to tail triggers release of serotonin at terminals of interneurons



Serotonin binds to G-protein-coupled-receptors in cell body and terminals of the sensory neuron

Adenylyl cyclase is activated and catalyses cyclic AMP (second messenger)

cAMP activates PKA

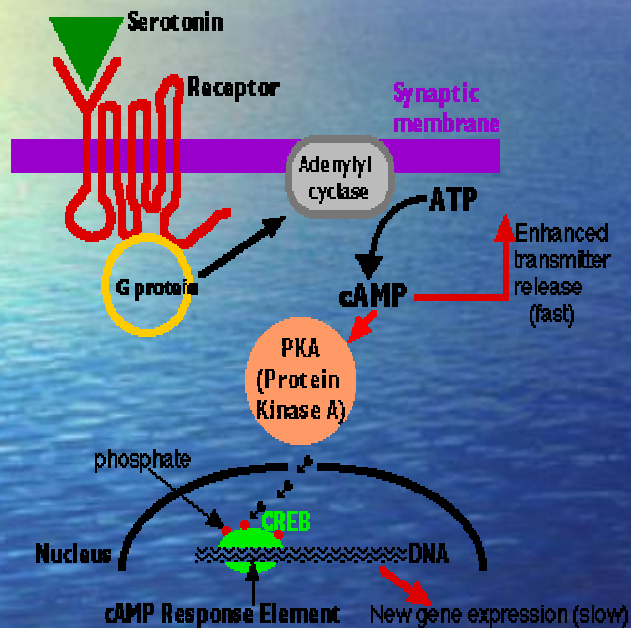
and increases the release of neurotransmitter at its synaptic connection to the motor neurons.

Result:

A longer period of gill-withdrawal in response to a light touch to the siphon

Facilitation:

- Long-Term Facilitation: Application of serotonin causes a higher level of cAMP some of the activated PKA moves into the nucleus There PKA phosphorylates and Activates CREB-1 (cAMP Response Element Binding protein-1) and binds the cAMP Response Element. (a DNA sequence in the promoters of many genes whose transcription and translation produce proteins) New synaptic connections are formed.

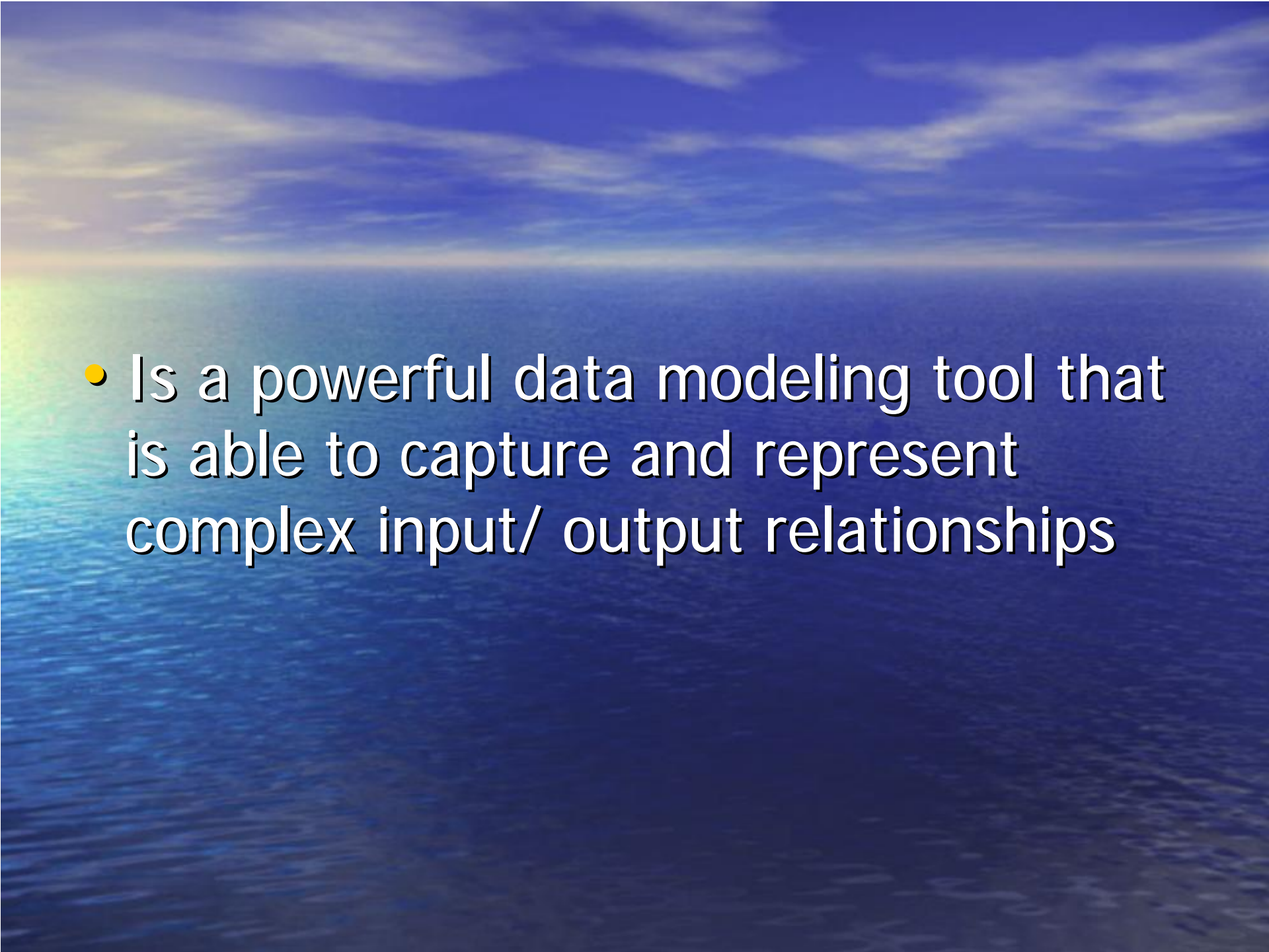


Short- and Long-term Memory

- Molecular Biology of Short- and Long-Term Memory Storage
- cAMP and Serotonine cause increased excitability and broadening of action potential (by reducing specific K^+ currents allowing greater Ca^{++} influx)
- The active catalytic subunit of cAMP dependent kinase produces broadening of the action potential and enhancement of glutamate release.

Neural Networks



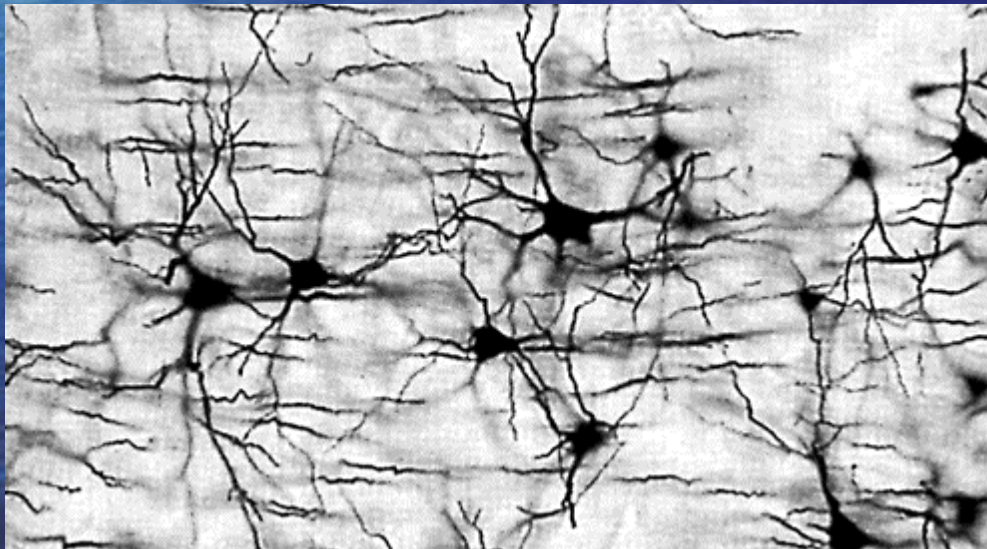
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- Is a powerful data modeling tool that is able to capture and represent complex input/ output relationships

Neural Networks are a form of multiprocessor computer system

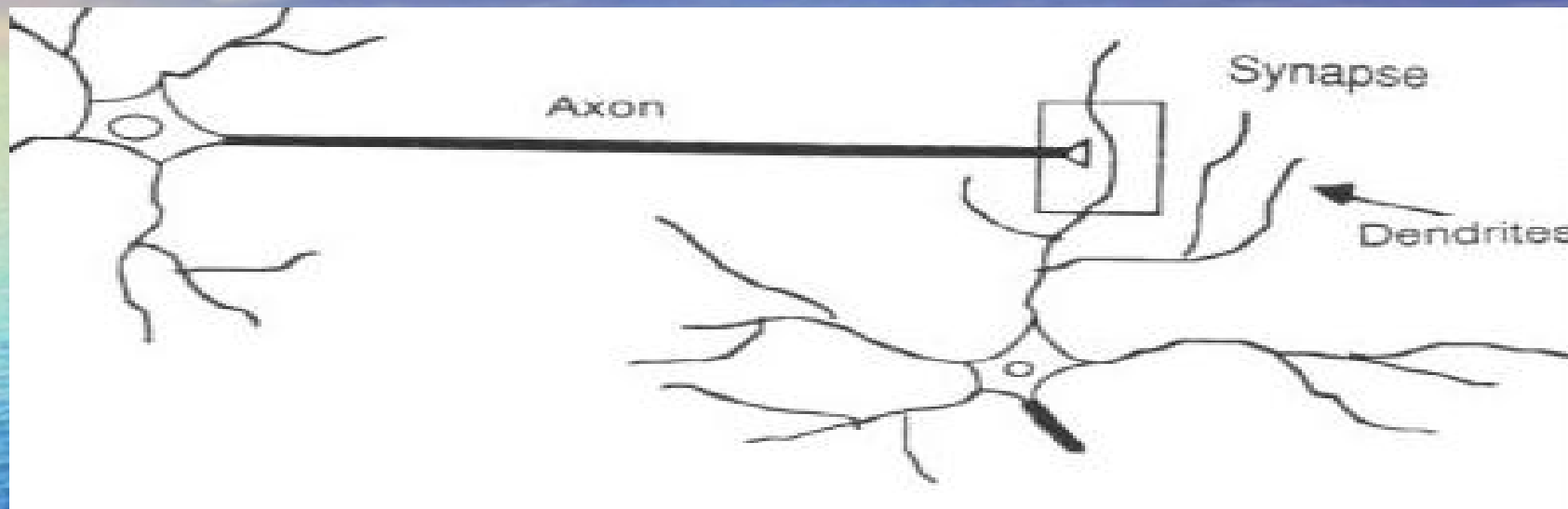
- Simple processing elements
- A high degree of interconnection
- Simple scalar messages
- Adaptive interactions between elements

Biological Neuron

- As many as 10.000 different inputs
- Send ist output to many other neurons
- Wired up in a 3- dimensional pattern



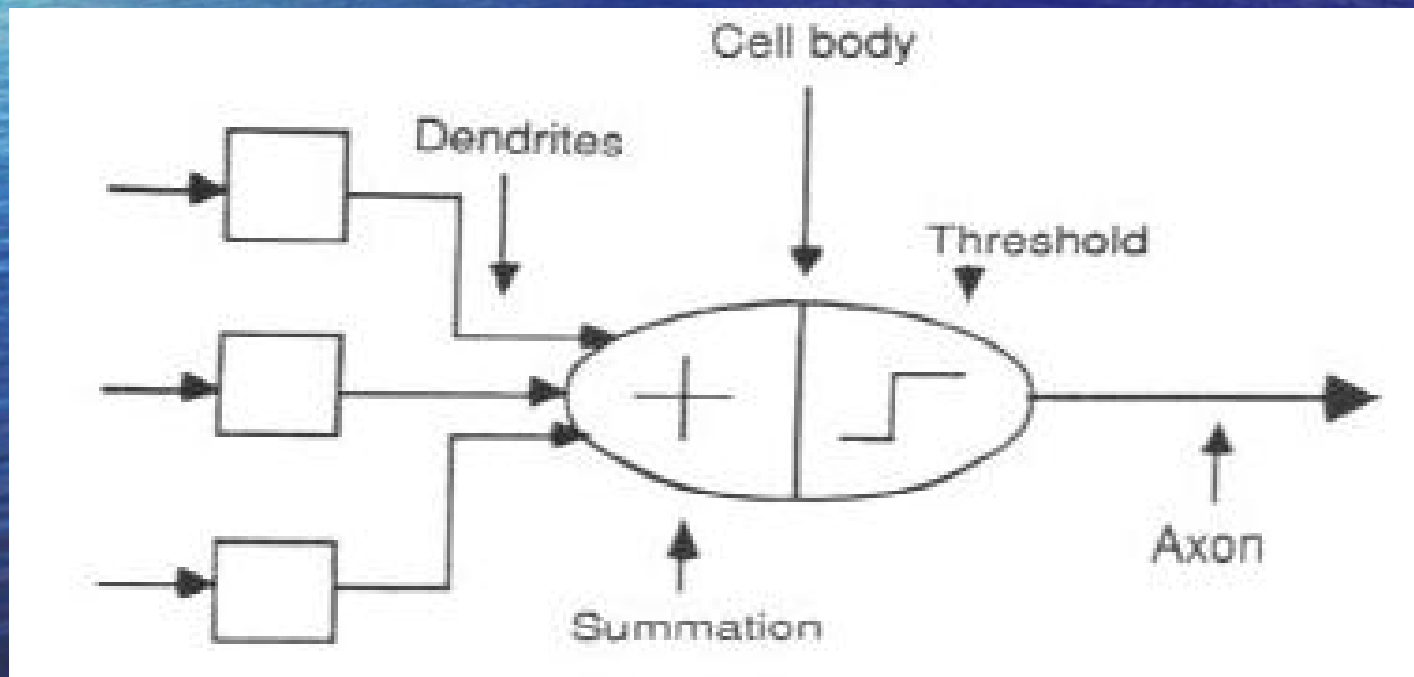
How the Human Brain Learns?



- a neuron receives excitatory input that is sufficiently large compared with its inhibitory input, it sends a spike of electrical activity down its axon
- **Learning:**
changing the effectiveness of the synapses so that the influence of one neuron on another change

From Human to Artificial Neurons

1. Deduce the essential features
2. Program a computer to simulate these features



How Artificial Neural Networks learn?

- Interconnected units → serve as model neurons
- Modifiable weight → synapse

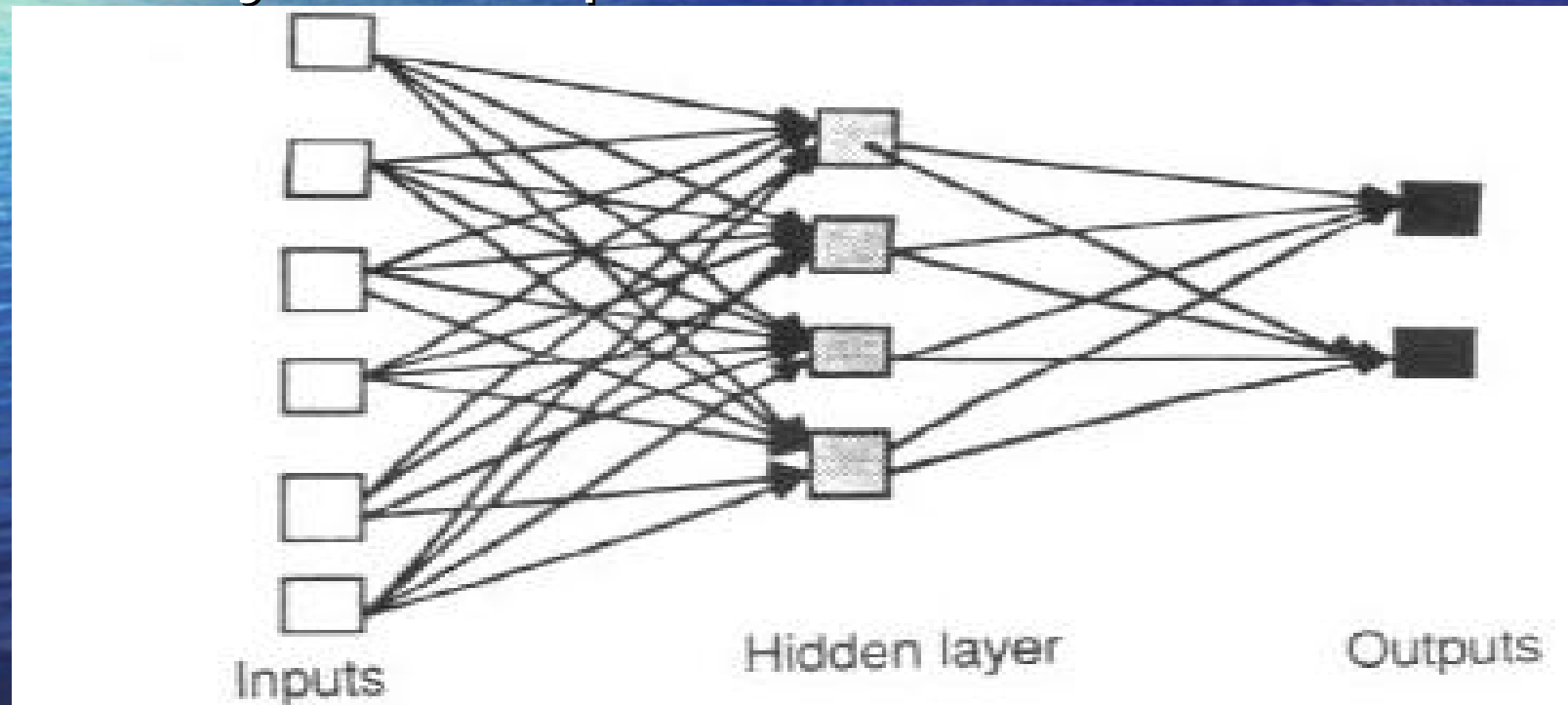
Performs this conversation in two stages:

1. Multiplies each incoming activity by the weight and adds together all weighted inputs → total input
2. Input- output function → outgoing activity

- Linear units
output activity is proportional to the total weighted output
- Threshold units
output is set at one of two levels, depending on the total input is greater than or less than some threshold values
- Sigmoid units
output varies continuously but linearly as the input changes

The most common type of ANN

- Layer of „input“ units
- Layer of „hidden“ units
- Layer of „output“ units

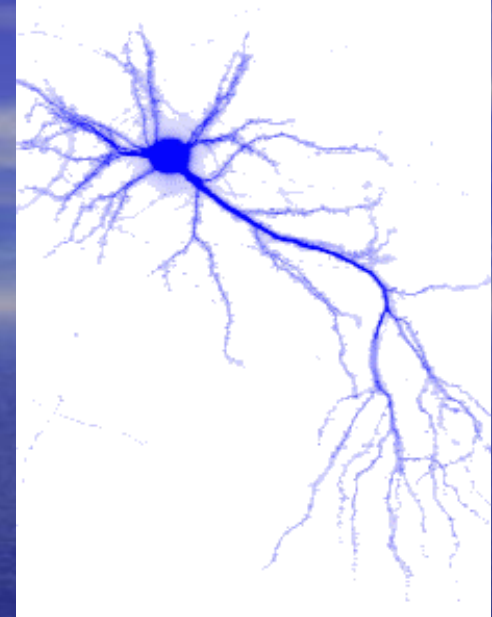


How to teach an ANN ?

1. Present the network with training examples, which consist of a pattern of activities for the input units together with the desired pattern of activities for the output units
2. Determine how closely the actual output of the network matches the desired output
3. Change the weight of each connection so that the network produces a better approximation of the desired output

HOPFIELD Network

- Introduction
- Description
- Simulation
 - Pattern and Correlation between them
 - States and Overlap
 - Example
- Conclusion



Introduction

- Simple artificial network analogical to the brain
- Able to store certain memories or patterns in a manner similar to the brain
- Nodes/pixels: simplified neurons
- 2 possible "states" - firing or not firing
- Full connectivity
- Change of state

Introduction

- The pattern of firing and non-firing nodes changes with time
- One node – signal – other node
- Some nodes fire later
- The certain pattern is established
- Some nodes remain „on“, others „off“

Introduction

- Recall of activity burned at the beginning
- Recalled memory - starting pattern
- Corrupted image: reconstruction of network
- Poor image: recall of incorrect memory

Description

- Neurons = pixels
- Take the values of -1 (off) or +1 (on)
- The network has stored a certain number of pixel patterns

Description

Connection between synapses

$$W_{ik} = (1/N) \sum_m X_i^m X_k^m$$

- W_{ik} : strength of connection between 2 synapses
- N : number of neurons
- m : certain pattern
- i, k : neurons
- X_i^m : value of neuron i in pattern number m

Theoretical capacity

$$p = a * N \quad p: \text{number of patterns}$$

$$a = 0.14$$

$$p \sim 0.14 * N$$

Simulation – Pattern and Correlation between them

- A pattern u is a specific pixel set $X^u_i = \pm 1$ defined for all N neurons

(pixels)

$$\{ X^u_i \mid 1 \leq i \leq N \}$$

- The patterns are labelled by the index u with

$$1 \leq u \leq p$$

Correlation between patterns u and v can be defined as

$$C^{uv} = (1/N) \sum_i X^u_i X^v_i$$

- N : number of neurons
- X^u_i : i th neuron of pattern u
- X^v_i : i th neuron of pattern v

Simulation - States and Overlap

- A network state is the set

$$\{ S_i(t) \mid 1 \leq i \leq N \}$$

S_i : neuronal activity

$S_i(t)$: +1 active neuron
(red pixel)

$S_i(t)$: -1 inactive neuron
(blue pixel)

at time t

- is one if the momentary state of the network is identical with one of the patterns

- is measure of similarity between the momentary network state and one of the patterns

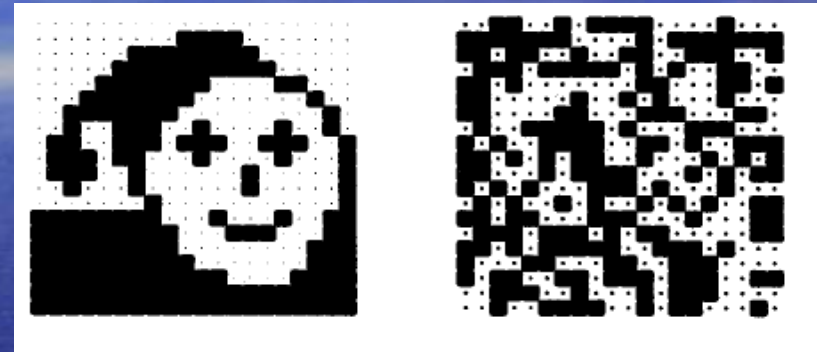
- e.g., the overlap with pattern u is defined as

$$m^u = (1/N) \sum_i (X_i^u S_i)$$

- X_i^u : i th neuron of pattern u
- S_i : neuronal activity

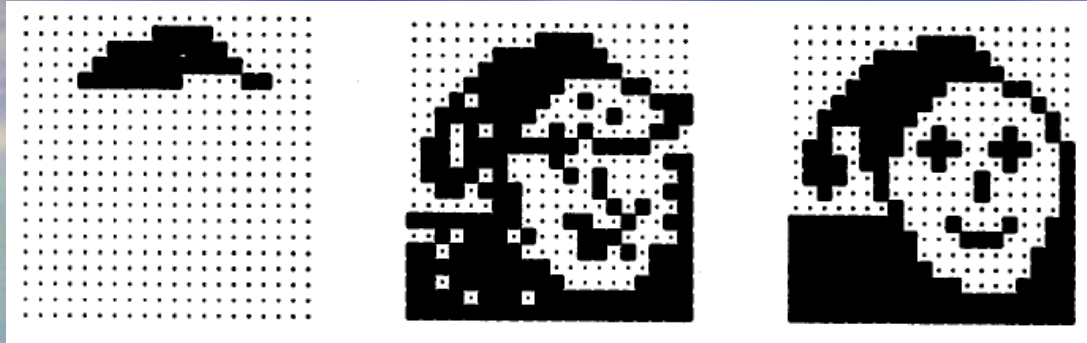
Simulation - Example

- Network of 400 neurons
- 20 patterns
- 1 recognizable pattern
- 19 random patterns
 - 50% white pixels
 - 50% black pixels
- White pixel = +1
- Black pixel = - 1

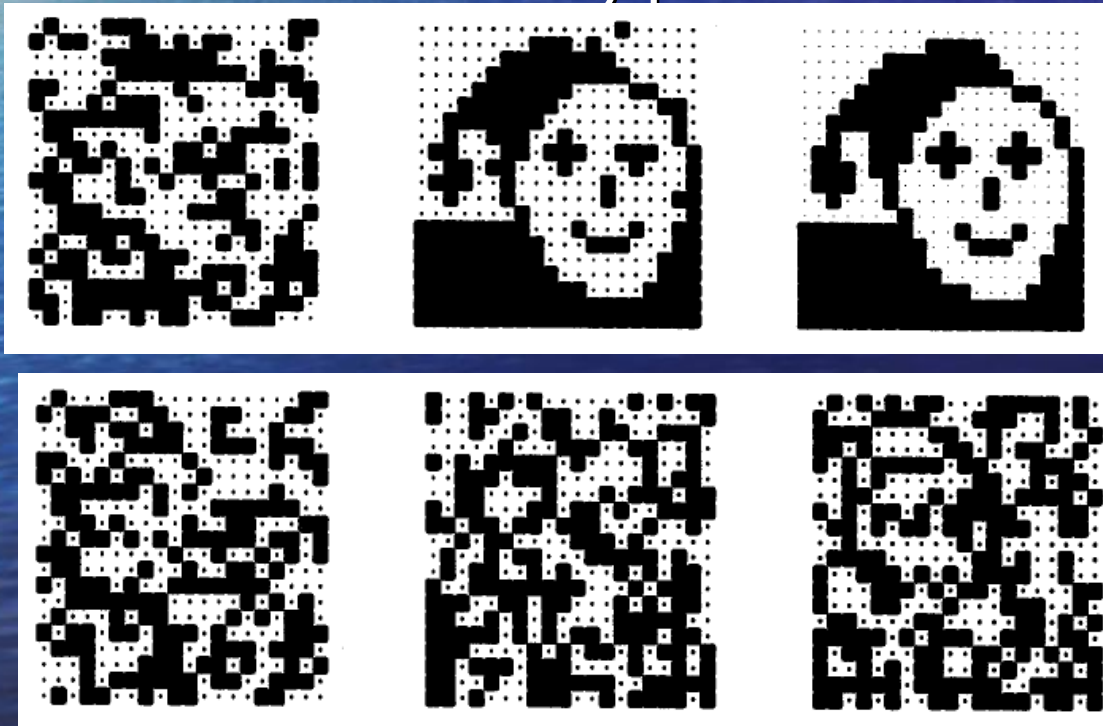


Simulation - Example

Completion of a fragmentary input pattern



Reconstruction of a noisy pattern



Hopfield Network - Conclusion

- „The Hopfield model is an artificial neural network designed to model the memory recall process of the brain“
- With a part of the original memory it is possible to present a perfect image
- Alteration of nodes - to some degree - doesn't cause lost of memory (up to 20%)

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