# DD2437 – Artificial Neural Networks and Deep Architectures (annda)

## Lecture 1: **Course introduction and fundamental concepts**

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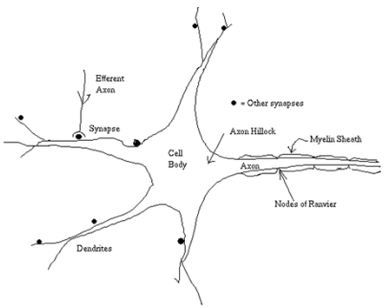
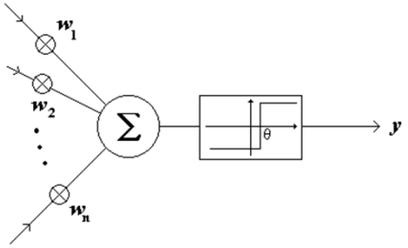
# Overview

- A historical note
- Course outline
  - Learning activities
  - Assessment, grading
- Introduction to ANNs
  - Fundamental characteristics
  - Brain inspirations
  - Current developments – theory and applications

# Brief history of ANNs

- McCulloch and Pitts
- Donald Hebb “The Organization of Behaviour”



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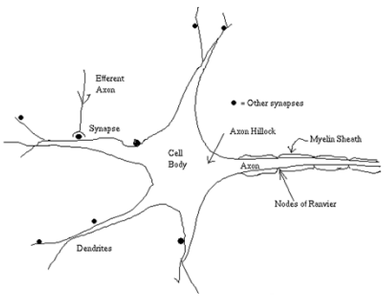


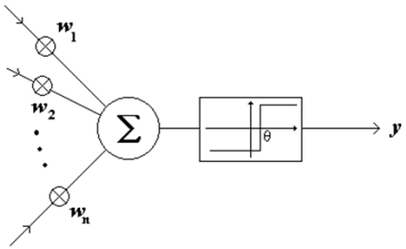


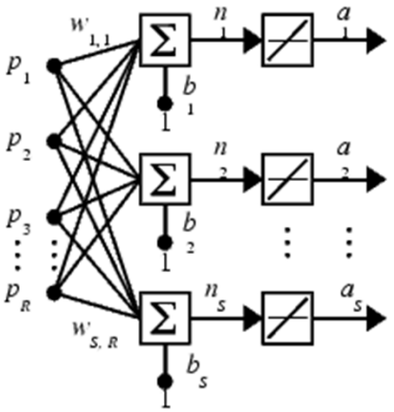

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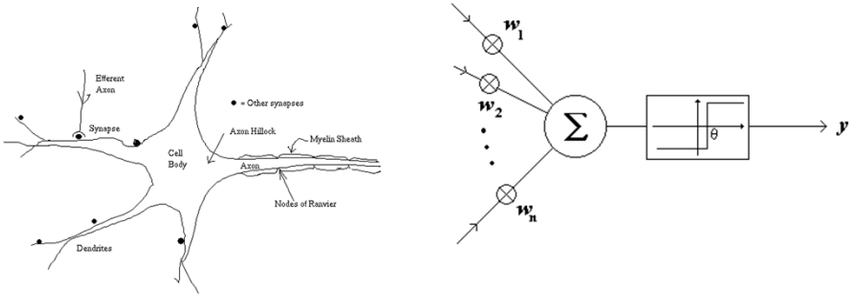
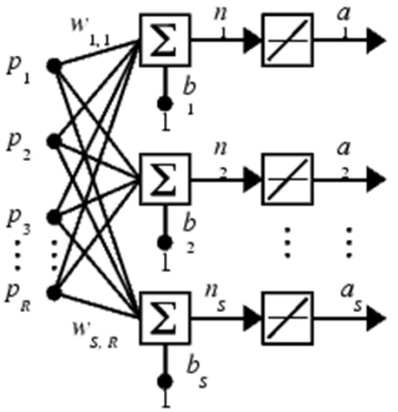
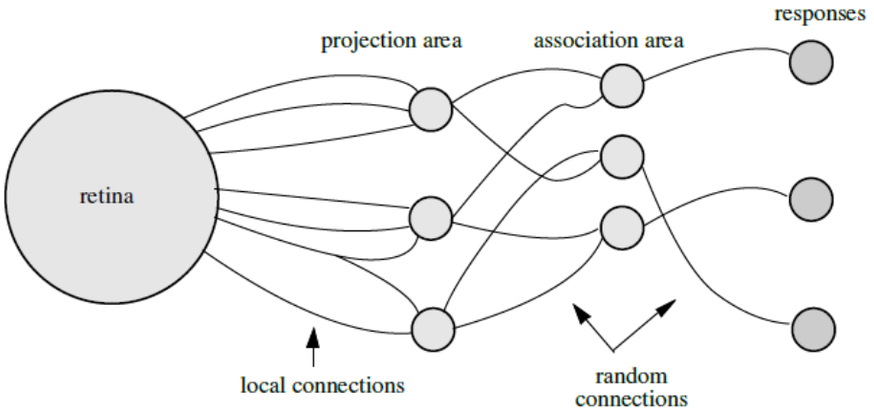
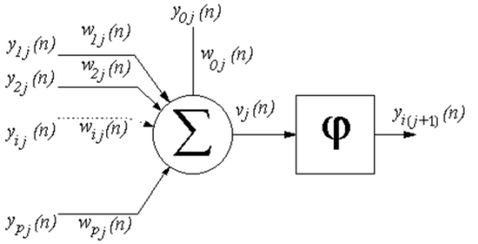
- Rosenblatt’s perceptron




After Rosenblatt (1958)

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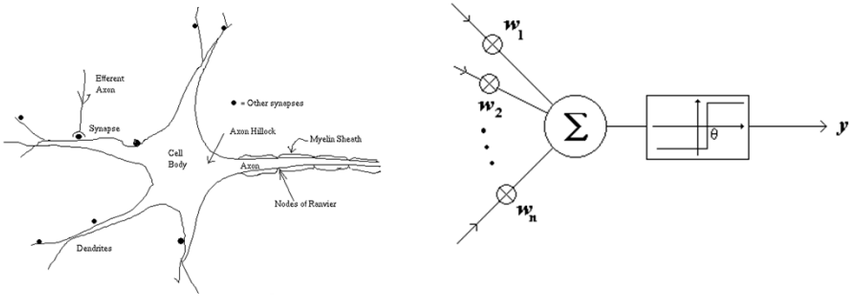
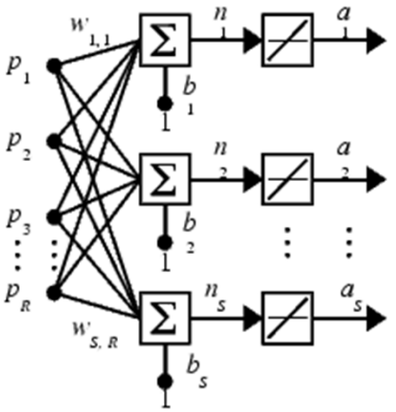
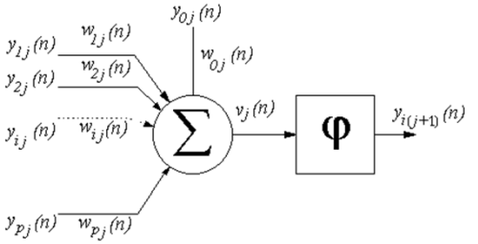
- McCulloch and Pitts
- Donald Hebb “The Organization of Behaviour”
- ADALINE for binary patterns by Widrow and Hoff
- Rosenblatt’s perceptron
- Marvin Minsky and Seymour Papert's criticism (1969)
- first AI winter:  fears and outrageous claims led to lower interest and poor funding

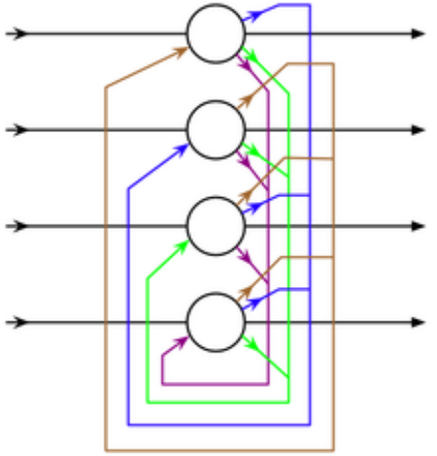


# Brief history of ANNs

- Hopfield's impact



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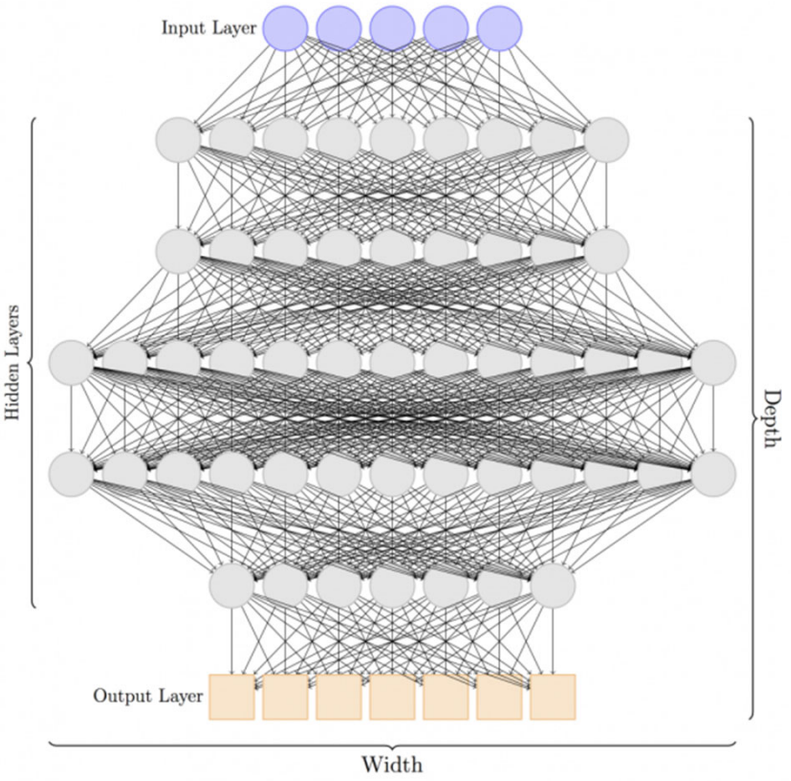
- Renewed enthusiasm in the 1980s and 1990s (backpropagation, 1986)
- interest swifts towards more mathematically rigorous statistical learning theory
- another revival of interest in deep neural networks



# A wide scope of applications

- Pattern recognition: classification and clustering
- General interpolation problems (generalisation)
- Data representations, coding and compression
- Signal processing
- Time series prediction
- System identification
- Decision support (e.g. medical or industrial diagnostics)
- Memory storage, modelling
- Optimisation, combinatorial problems
- etc…….

# Course outline

- Learning activities
  - 10 lecture topics (12 sessions) in 4 modules + 1 summary and Q&A lecture
  - 10 lab review sessions
  - 4 lab assignments (in groups of 3 students)

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  - 10 lab review sessions
  - 4 lab assignments (in groups of 3 students)
- Assessment, grading
  - 4 mandatory lab assignments with bonus point deadlines
  - lab review (redovisning) and a short report to submit in Canvas (P/F)
  - exam: A-F

# Distance learning (annda20HT)

- Please read up on details in Canvas (NEW! Distance learning HT2020)
- Key aspects of distance learning (off-campus)
  - Digital lectures in Zoom with varying formats (from live lectures to "flipped classroom" activities; synchronous/asynchronous mode)
  - Pre-recorded videos, reading material, group discussions, case studies – please **be prepared** and **participate online** in the scheduled lecture slots
  - Online lab reviews in Zoom (please form groups and sing up for the pre-existing groups in Canvas, do not create any new student groups)
  - Digital exam in Canvas (quiz + written part)
  - We will heavily rely on digital platforms: Zoom, Canvas and TalkMath

# Distance learning (annda20HT)

- Extra things to realise and reflect on
  - Challenges of distance learning, studying from home
    - Depending on your work-style, working from home can either save you from distractions and commuting time, or deprive you from stimulating personal interactions
    - Structure your day:
      - Get up at fixed times, get dressed for work
      - Separate work from free time
      - Organize (web) meetings
      - Use opportunities for interactive learning

# Distance learning (annda20HT)

- Extra things to realise and reflect on
  - Challenges of distance learning, studying from home
  - Experimental setup of online lecture sessions with enhanced interactive activities and flipped classroom
    - Varying formats for us to test (your feedback is much appreciated!)
    - For lectures with pre-recorded videos (incl. flipped classrooms), please
      - watch video beforehand, read recommended material
      - in the lecture session, we will summarise, discuss & integrate material,
      - opportunities for questions and group discussions (learning from peers)
    - Please participate in all sessions and be active
    - Make the most of synchronous activities and complement them with asynchronous studying

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- Extra things to realise and reflect on
  - Challenges of distance learning, studying from home
  - Experimental setup of online lecture sessions with enhanced interactive activities and flipped classroom
  - Extra material to digest (self-study): pre-recorded videos, quizzes
    - It is important that you follow the pace of the course
    - Quizzes offer an extra opportunity to monitor your own progress

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  - Experimental setup of online lecture sessions with enhanced interactive activities and flipped classroom
  - Extra material to digest (self-study): pre-recorded videos, quizzes
  - How to participate in Zoom sessions: from formalities to practicalities
    - Recording Zoom sessions and your online participation
    - Making use of **chat**, **"raise hand"** (students) and breakout room, polls (teacher) functionalities
    - Practical aspects: webcam, muting, taking notes, your environment
    - A single Zoom link for all lecture sessions

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  - How to participate in Zoom sessions: from practicalities to formalities
  - Importance of finding your ways around digital platforms: Zoom, Canvas and TalkMath

# Lab report

- a concise document to be uploaded to Canvas as a pdf file
- a typical layout involves
  - clear header (lab title, course signature, list of authors)
  - aim/scope of the lab assignment, assumptions, tools used
  - main results/findings supported with figures or tables along with short commentary
  - reflections, open questions and conclusions (to the point)
  - no code needed
- submission deadline is only concerned with bonus points (add a group in Canvas with the concatenated surnames as the group name) – please make one submission per group

# Lab review

- only 10-min demonstration of the lab results (in groups), we do not tend to inspect your code
- time is short so planning and preparation are critical –
  - focus on main points, key questions – what is the lab about?
  - what are the assumptions?
  - share your insights and formulate clear conclusions
  - what did you learn?
  - are there any open questions left?
- you are in charge of the lab review but we are likely to ask questions
- please ensure the entire group is involved (time sharing)
- please demonstrate in the form of a report with clear & clean figures

# Course content

## Lectures

L1: Course introduction and fundamental concepts (Jan 18)

L2: From perceptron learning rule to backpropagation in feedforward networks - supervised learning (Jan 19)

L3: Generalization, regularization, model selection and validation (Jan 22)

L4: Practical aspects of ANN approaches to pattern recognition problems (Jan 24)

L5: Radial basis function networks and introduction to unsupervised learning (Jan 29)

L6: Self-organising maps (Feb 9)

# Course content

## Lectures

L7a: Hopfield networks and introduction to stochastic networks

L7b: Boltzmann machines and RBMs

L8: Temporal processing with ANNs: feedforward vs recurrent network architectures

L9: Deep learning fundamentals: general philosophy and a review of deep architectures

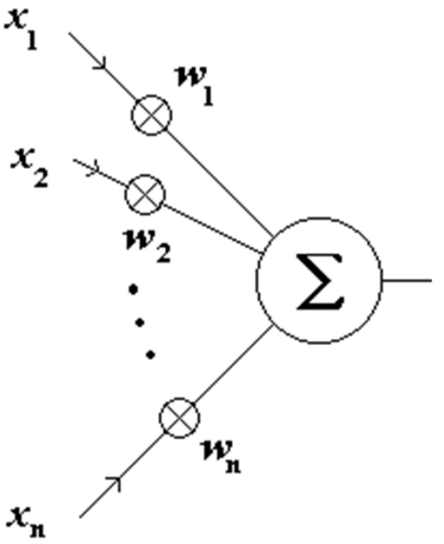
L10: Representation learning and deep generative models

L11: Deep neural networks: practicalities, challenges and current trends

L12: Course summary, old exam questions, Q&A

# Fundamental characteristics

- **nodes, units**
- activation function
- learning rule
- topology, network architecture
- data



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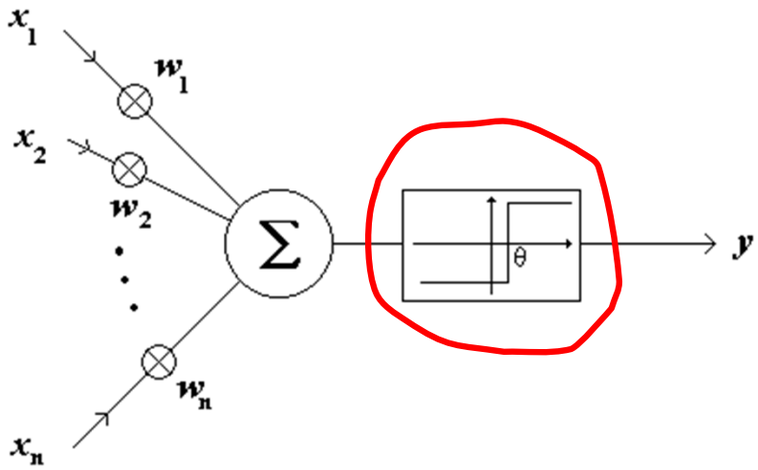


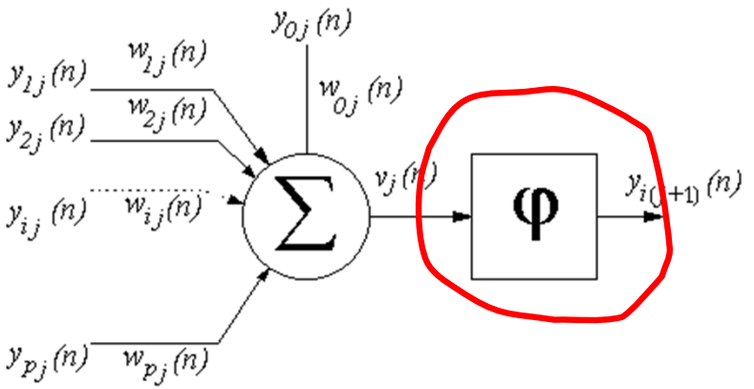

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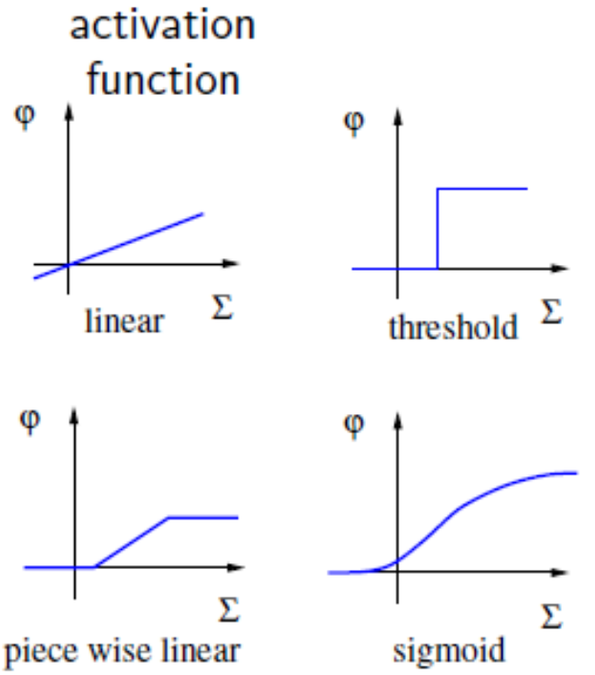


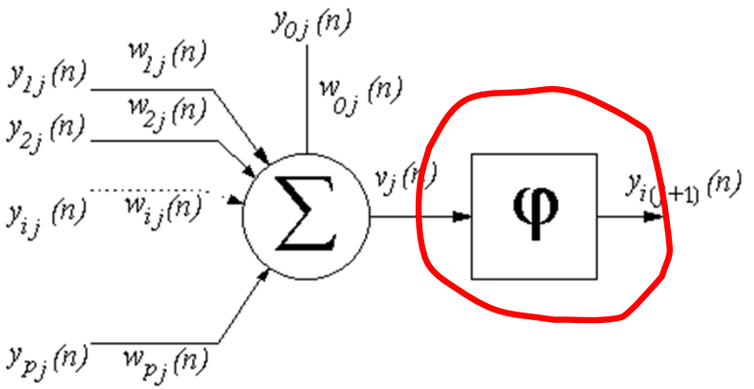

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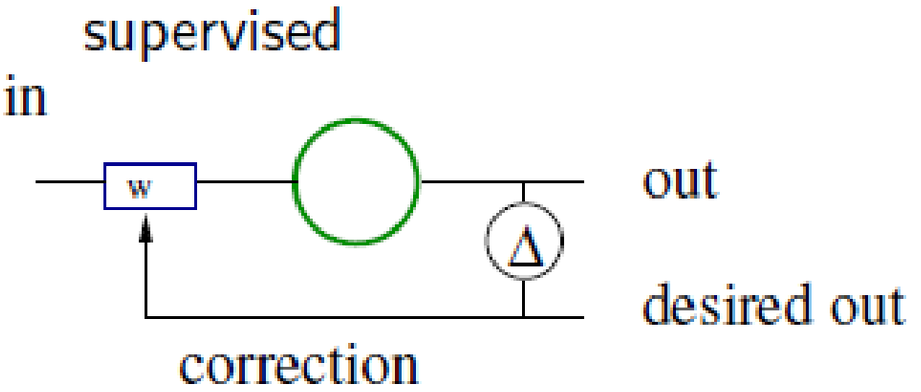

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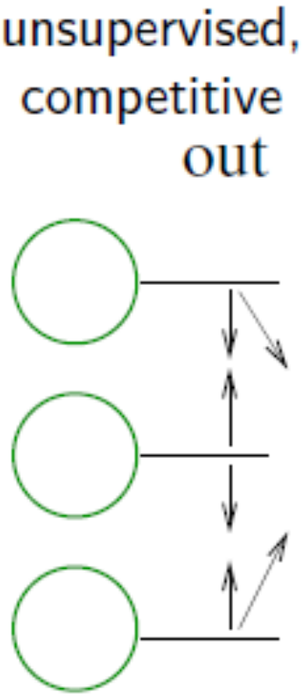

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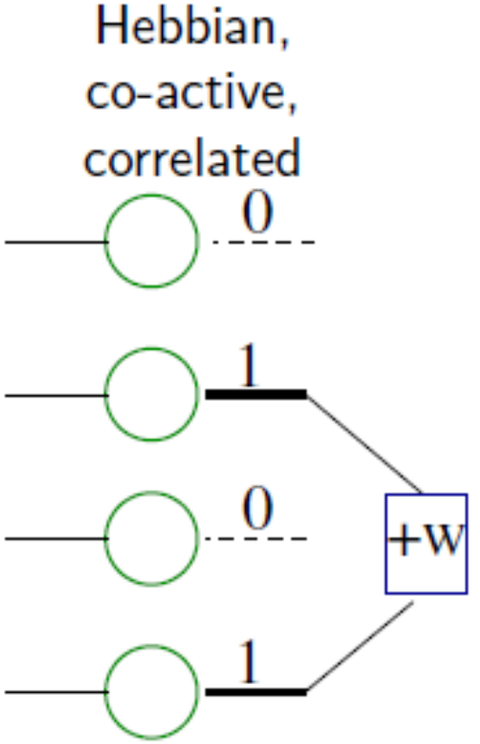

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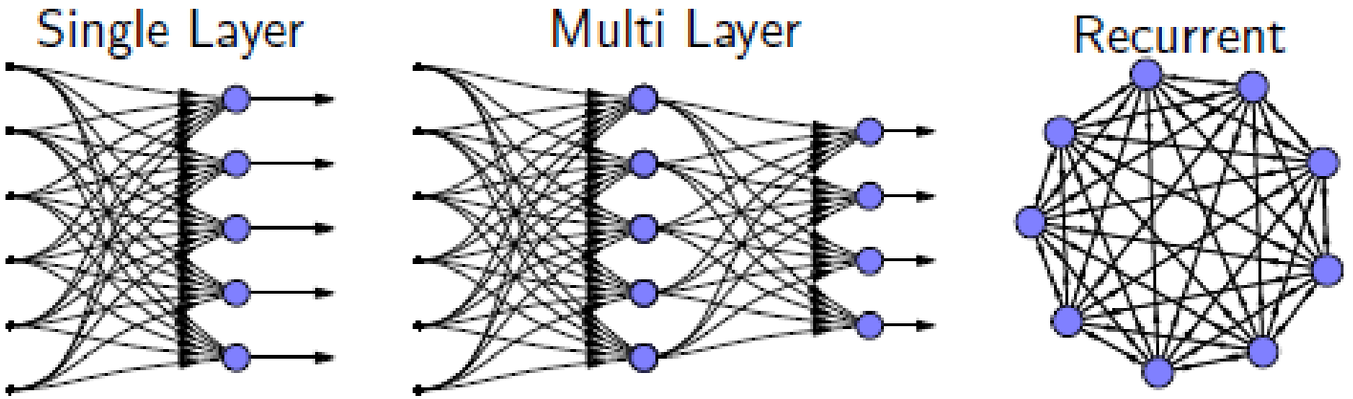

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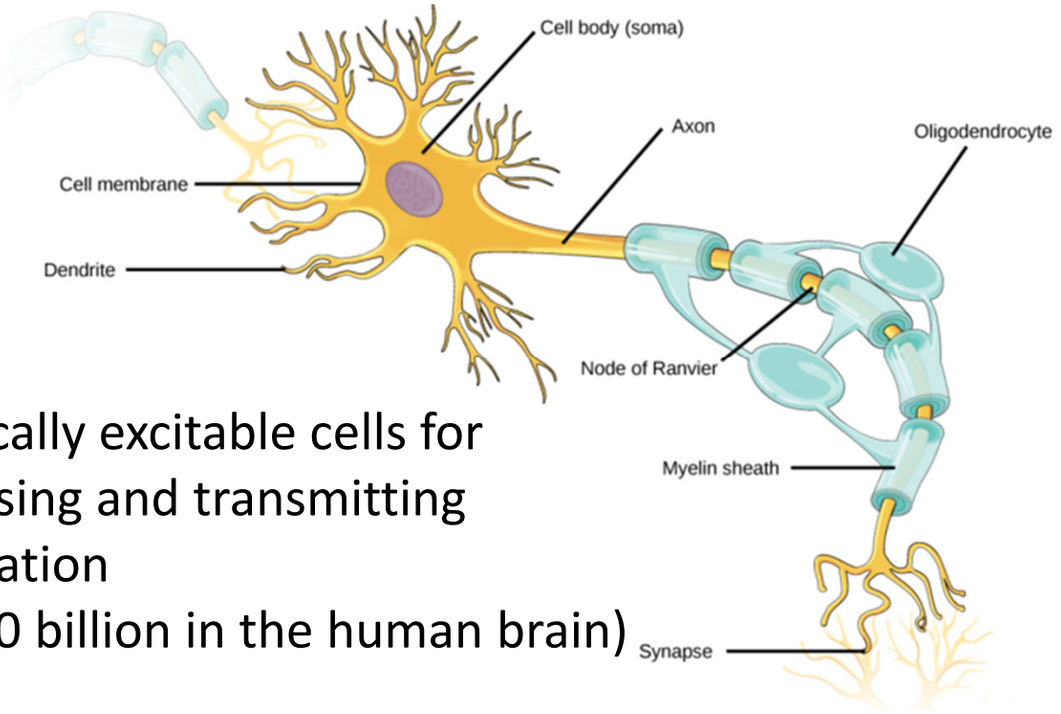
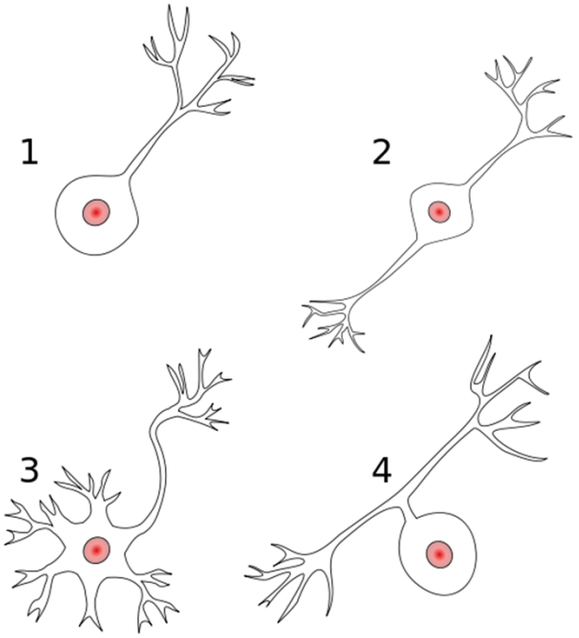
# Biomimetic nature of ANNs

## Inspirations from biology




electrically excitable cells for processing and transmitting information
(ca. 100 billion in the human brain)

Multitude of neuron types in the brain



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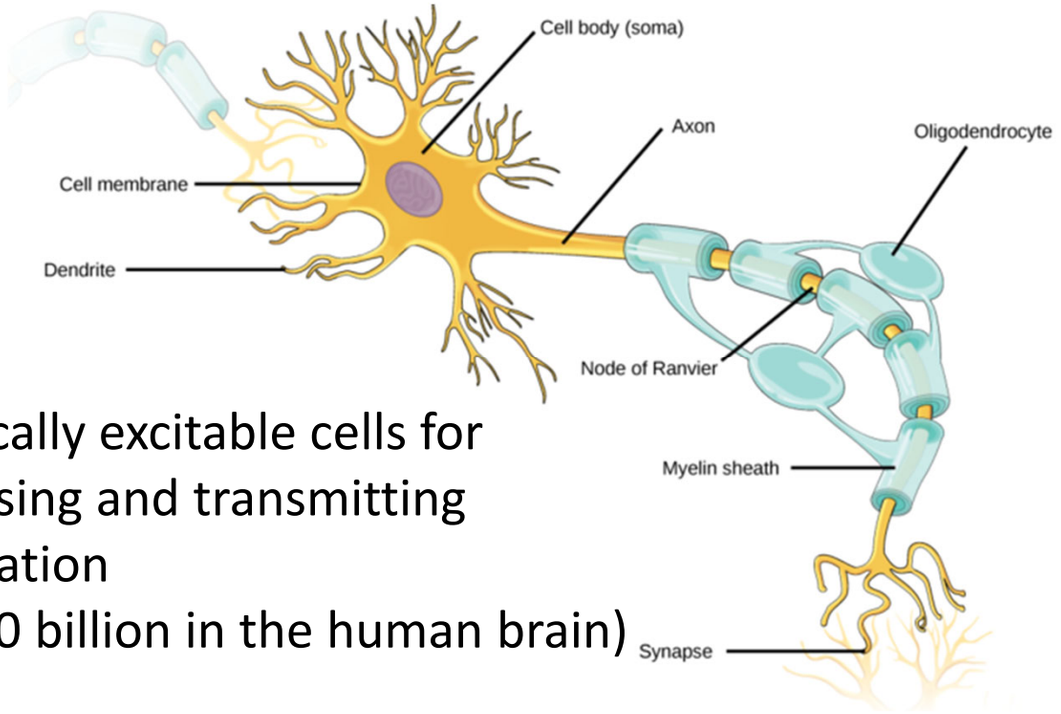


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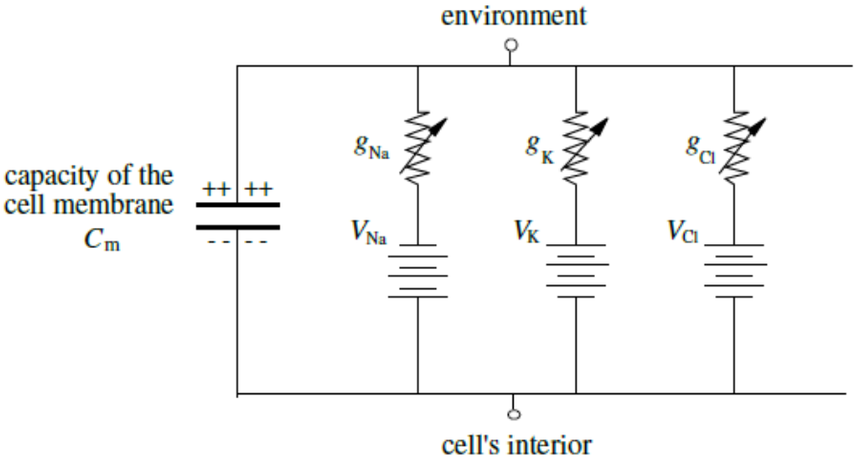
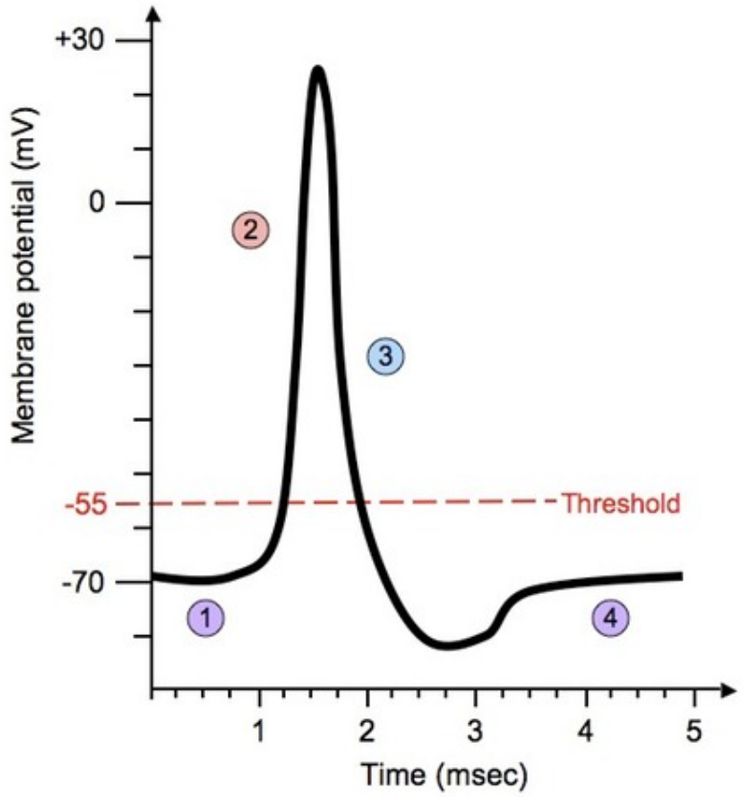
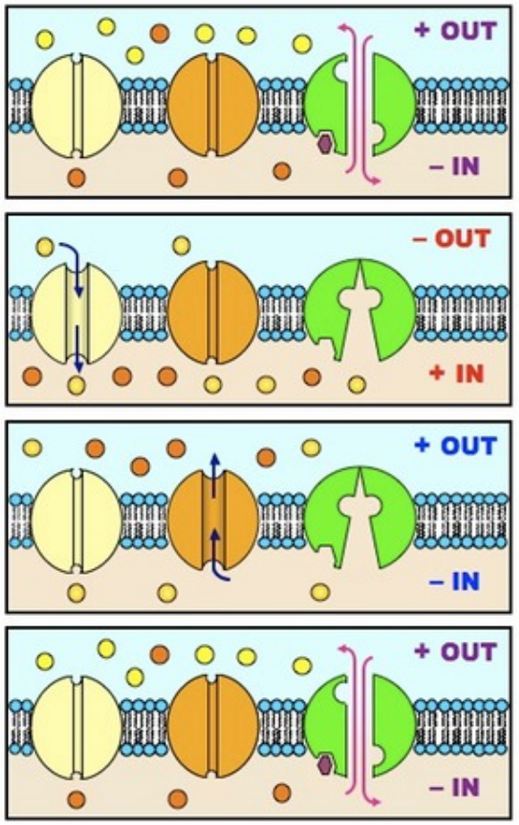


# Biomimetic nature of ANNs

## Inspirations from biology – action potential (firing)




1 **Resting Potential**
$Na^+/K^+$ pump

2 **Depolarisation**
Voltage-gated $Na^+$ channel

3 **Repolarisation**
Voltage-gated $K^+$ channel

4 **Resting Potential**
$Na^+/K^+$ pump

# Biomimetic nature of ANNs

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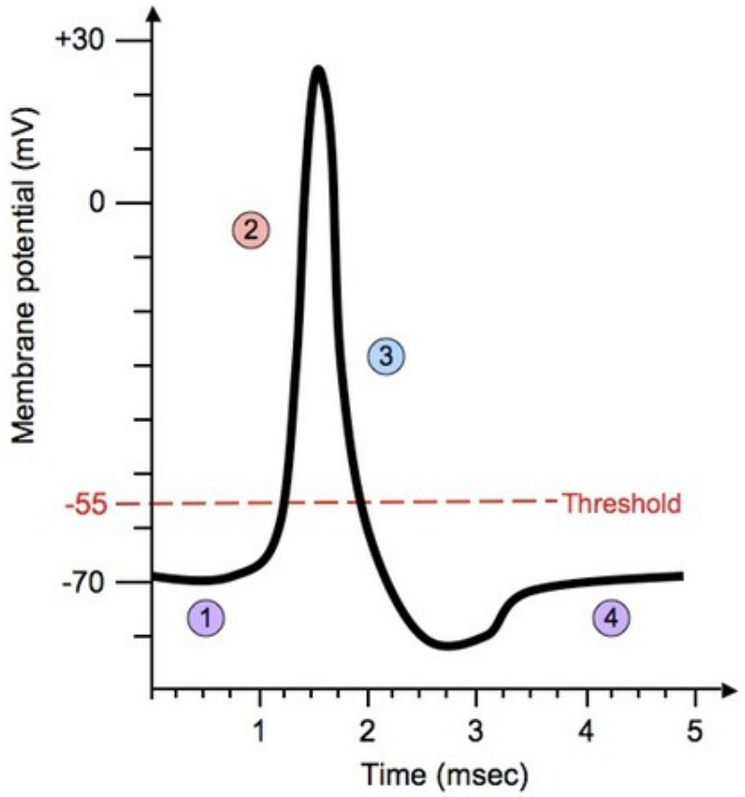


- commonly referred to as “spike” (nerve impulse)
- threshold phenomenon accounts for “all-or-nothing” paradigm
- spike (action potential of fixed amplitude) travels along the axon

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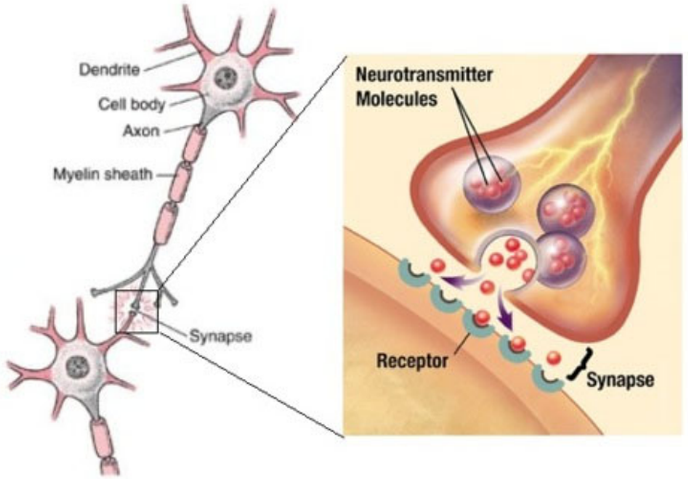


- commonly referred to as “spike” (nerve impulse)
- threshold phenomenon accounts for “all-or-nothing” paradigm
- spike (action potential of fixed amplitude) travels along the axon
- when spike reaches synaptic terminal, it contributes to post-synaptic potentials

# Biomimetic nature of ANNs

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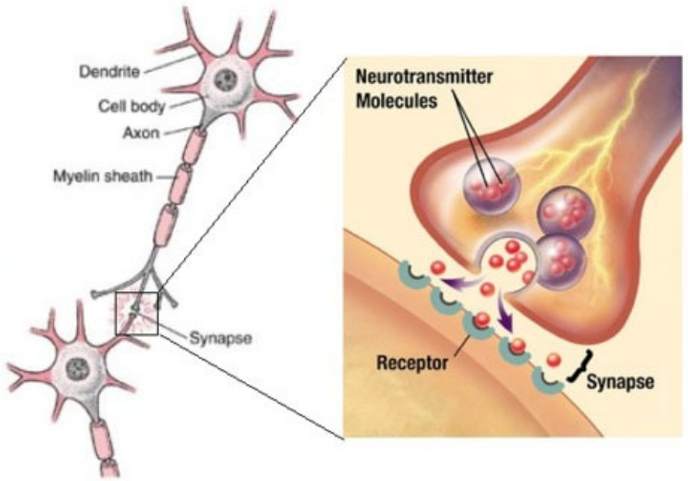
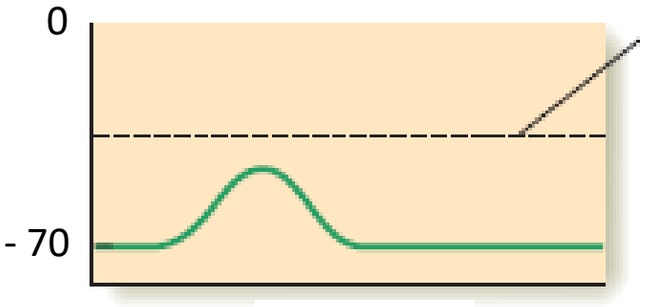
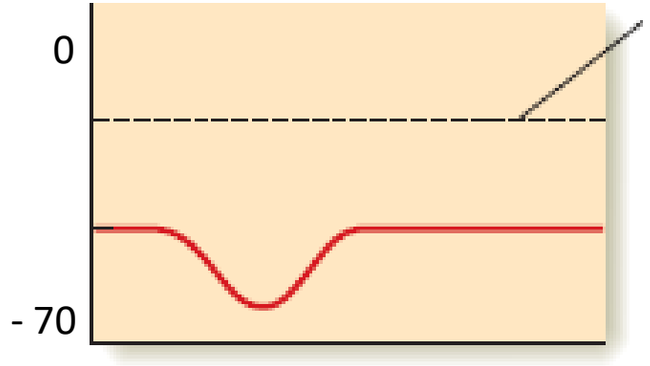



Level of depolarization needed to trigger an action potential

Depolarization
(Excitatory)




Level needed to trigger an action potential

Hyperpolarization
(Inhibitory)

# Biomimetic nature of ANNs

## Biological neurons and networks – computational aspects

- numerous simple units (type of integrators)
- binary communication – spike (“all-or-nothing”)
- but analog transmission in synapse (connection weight)
- many inputs, interconnect
- summation (integration) of inputs

# Biomimetic nature of ANNs

## Biological neurons and networks – computational aspects

- local processing, learning (based on local information)
- synaptic memory (memory stored in weights)
- synaptic plasticity – weight adaptation according to learning rules (largely phenomenological)
- weights can be positive and negative (but Dale's law)
- fast nature of parallel processing
- tolerance to errors/noise in data, weights etc.