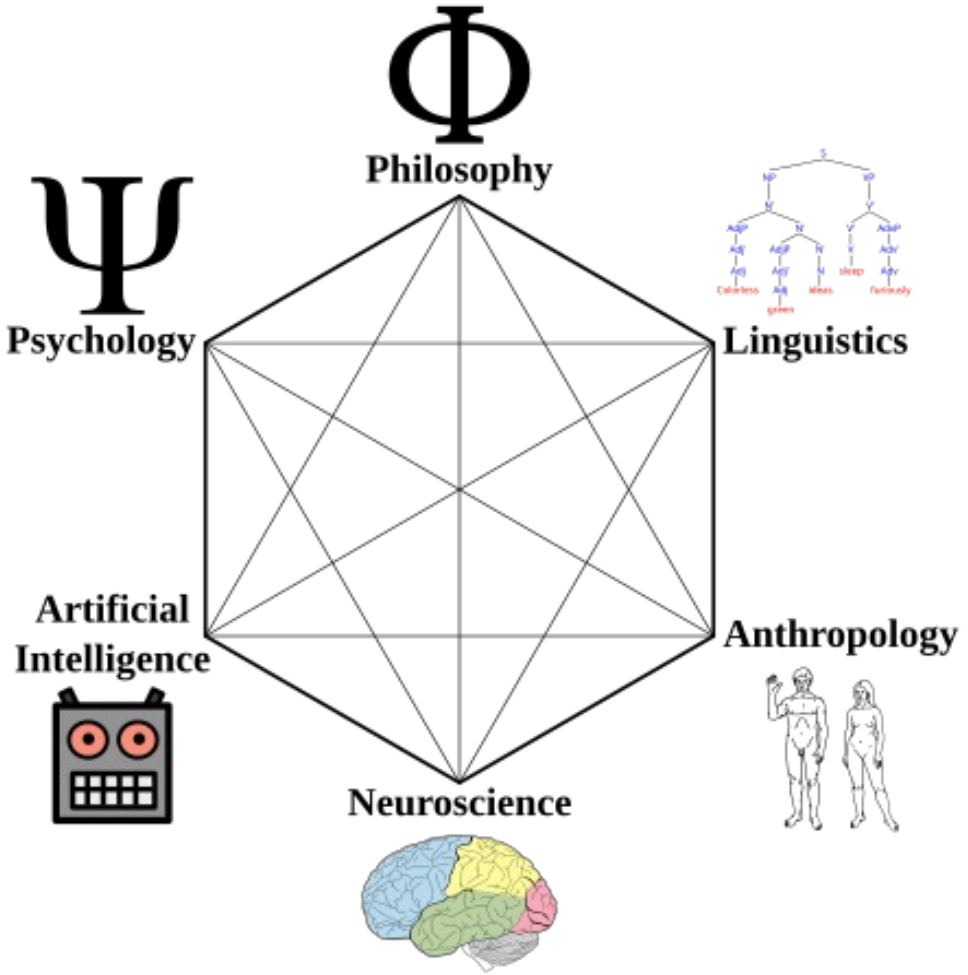
# Introduction to Cognitive Science

(1)

# General information

- skansi.sandro@gmail.com
- Consultations: per request
- Exam: oral
- Student obligations (besides the exam): active participation and experiment exposition (seminar)
- Reading: Bermudez, J. L. Introduction to Cognitive Science (3rd edition or later), CUP.
- Nice to have at hand (useful, not required): PDF of S. Blackburn's Oxford Dictionary of Philosophy

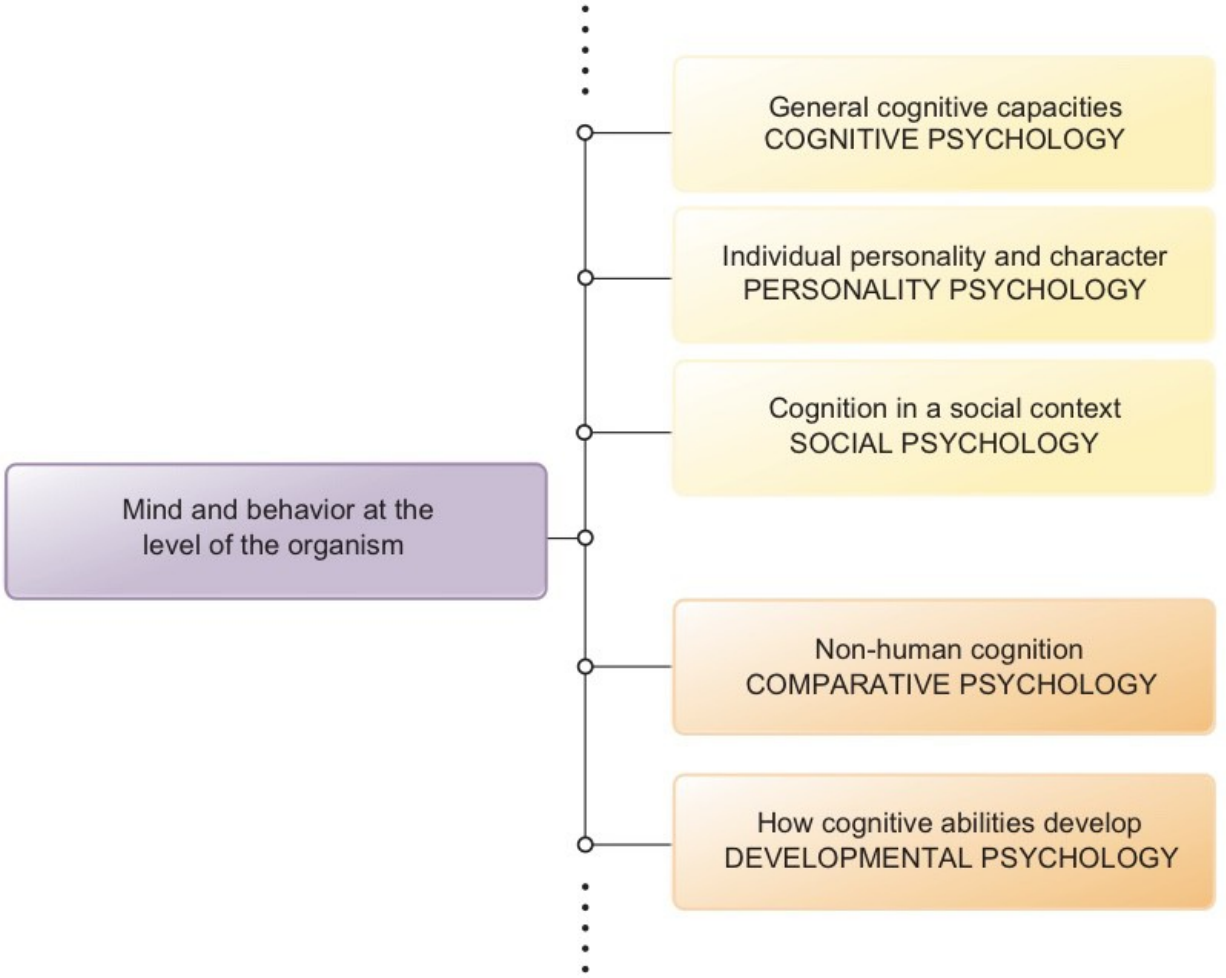
# Components of cognitive science (aka "hexagon")



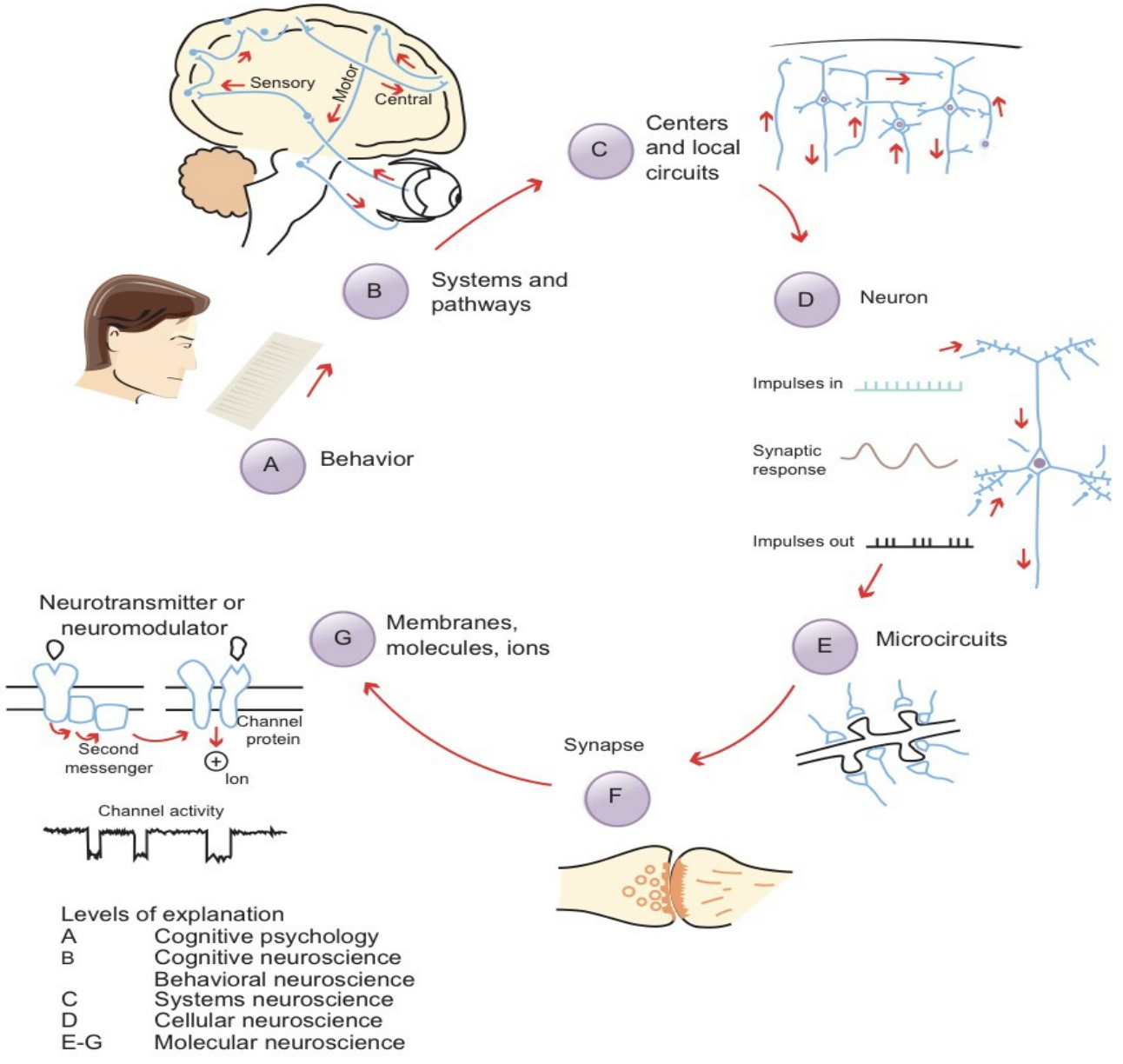
# Major issue for CogSci

- How to bring these sciences together (they sometimes have a radically different and incommensurable perspectives)
- Some CogSci ideas that might help:
  - Physical systems hypothesis: all information processing involves the manipulation of physical systems
  - Modularity: the mind has specialized modules, and no generalist capabilities other than those achieved as simple interactions of the modules
  - Embedded cognition: the brain is not the only cognitive organ

# How psychology is organized



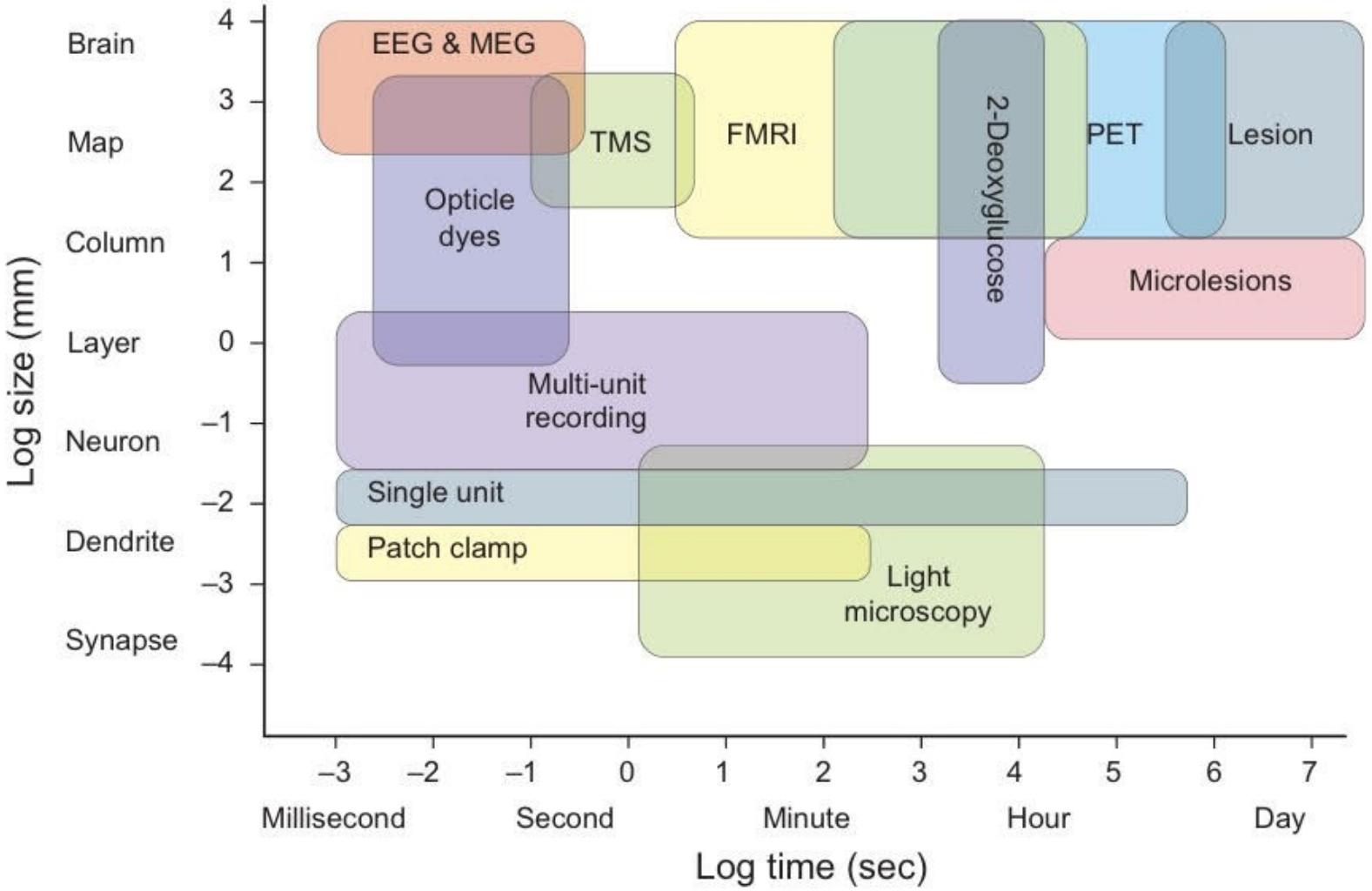
# How neuroscience is organized



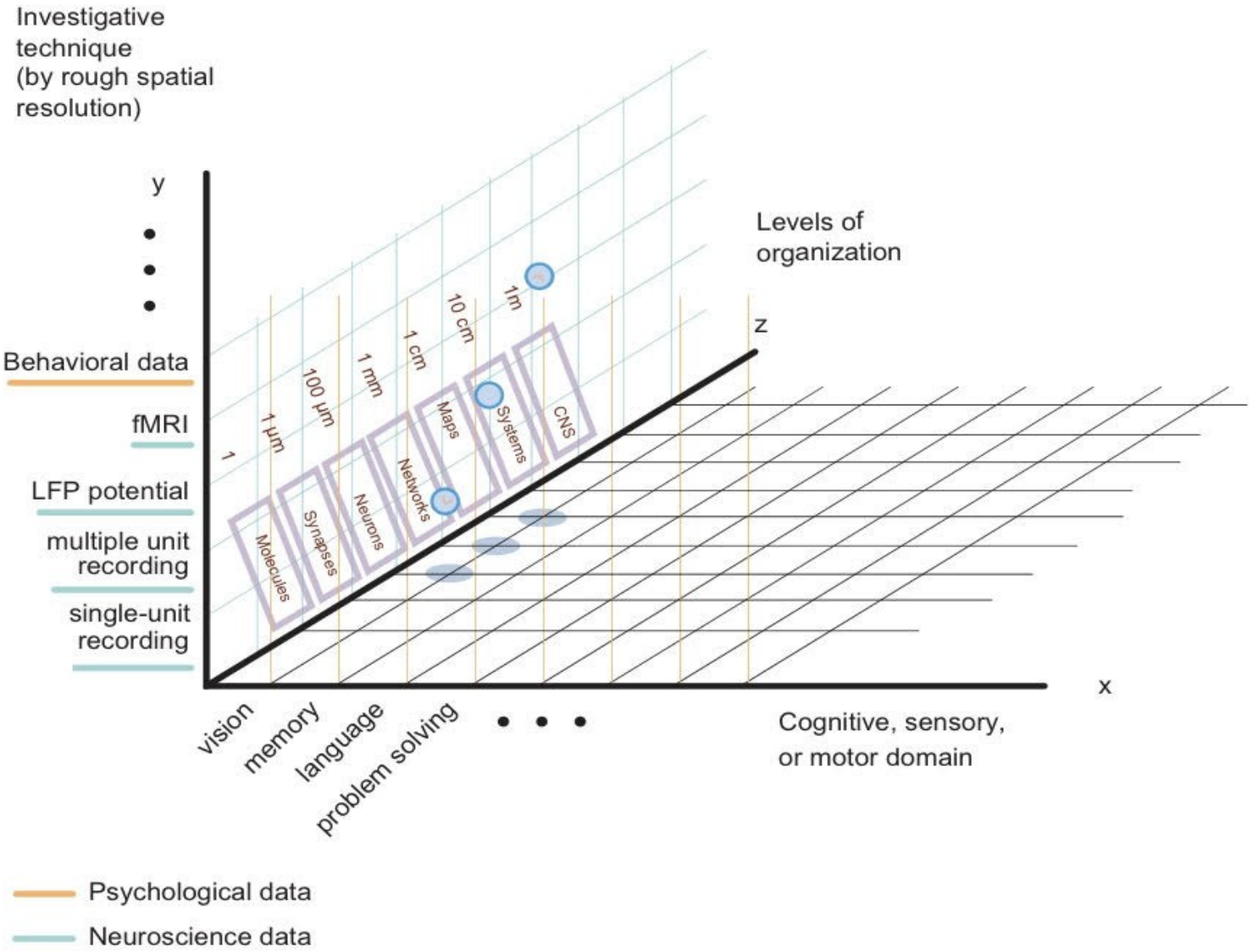
# Other four components of CogSci

- Philosophy?
  - Logic, epistemology, philosophy of mind, ethics... Teleology (not theology!)? Anthropology?
- AI?
  - ML, Knowledge Representation, Multi-agent systems, logic... NLP? CV?
- Linguistics?
- Anthropology?

# Problems with techniques in CogSci (inherited from Neuroscience)



# Three levels of organization of CogSci



# Prehistory of CogSci

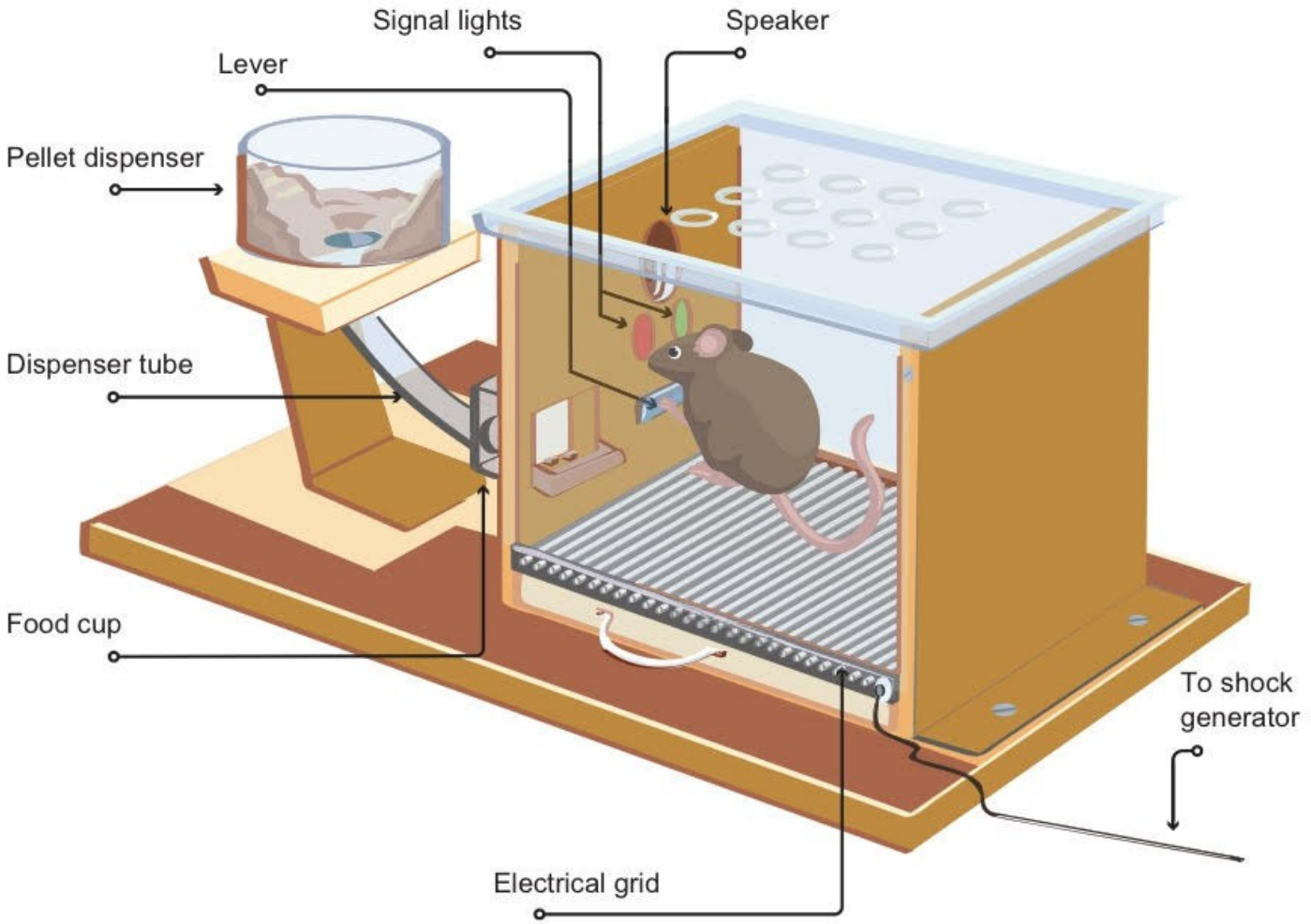
- Reaction against behaviourism in psychology
  - Some behaviour cannot be explained within the stimulus-response framework
  - The emergence of information-processing models in psychology
- The idea of algorithmic computation in logic
  - This again feeds in the idea of using information processing models
- The emergence of linguistics as a formal analysis of language

# Learning without Reinforcement (1930, Tolman and Honzik)

- Behaviourism
  - First assumption: all learning is conditioning
  - Skinner box
  - All learning either reinforcement learning (conditioned) or associations (unconditioned, even simpler)

  Not true even for rats!

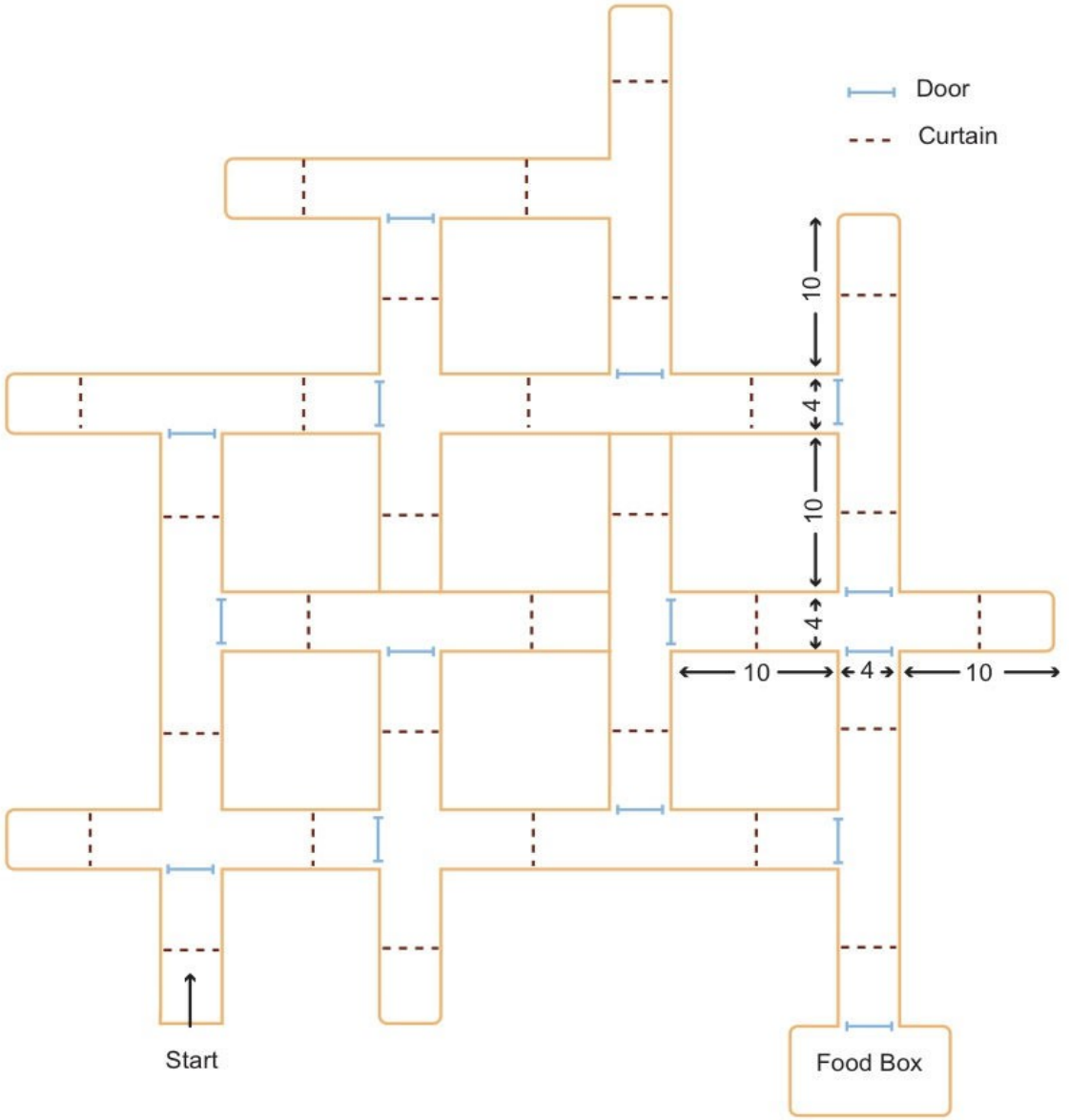
# A rat in a Skinner box



# How rats navigate mazes?

- Three groups of rats
  - Group A: reward each time for successful completion
  - Group B: no reward
  - Group C: unrewarded first ten days, then rewarded
- (Result) Once group C started getting the reward, they were the fastest group
  - Tolman and Honzik concluded that in the unrewarded period there was latent learning of the maze, which enabled faster navigation later

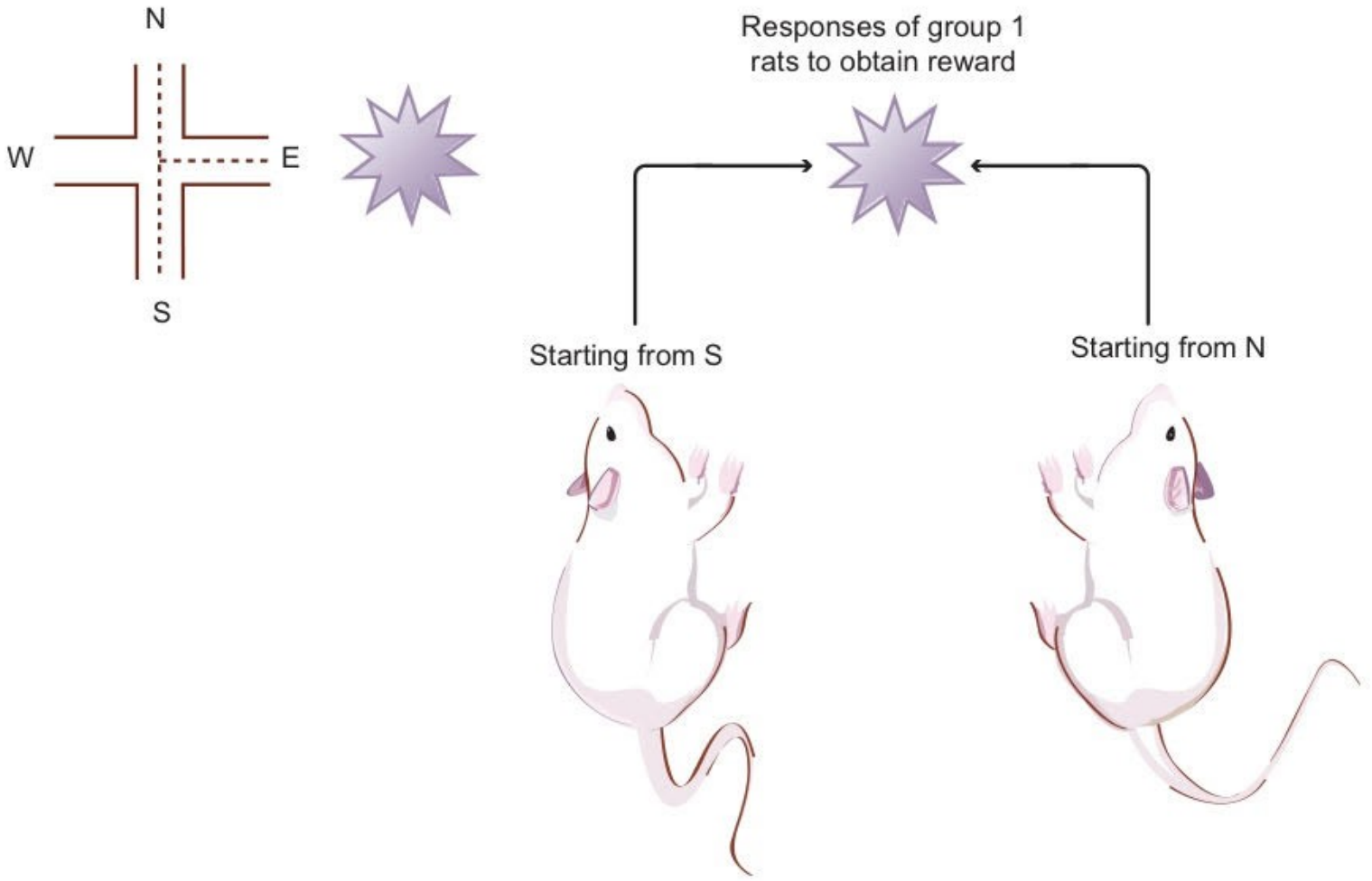
# Maze



# Cognitive maps in rats (1946, Tolman, Ritchie, Kalish)

- Cross-maze, four end points (N, E, W, S)
  - Group 1a: starts from N, reward E
  - Group 1b: starts from S, reward E
  - Group 2a: starts from S, reward E
  - Group 2b: starts from N, reward W
- (Result) Group 1 learned faster
  - Rats construct what they called "cognitive maps"

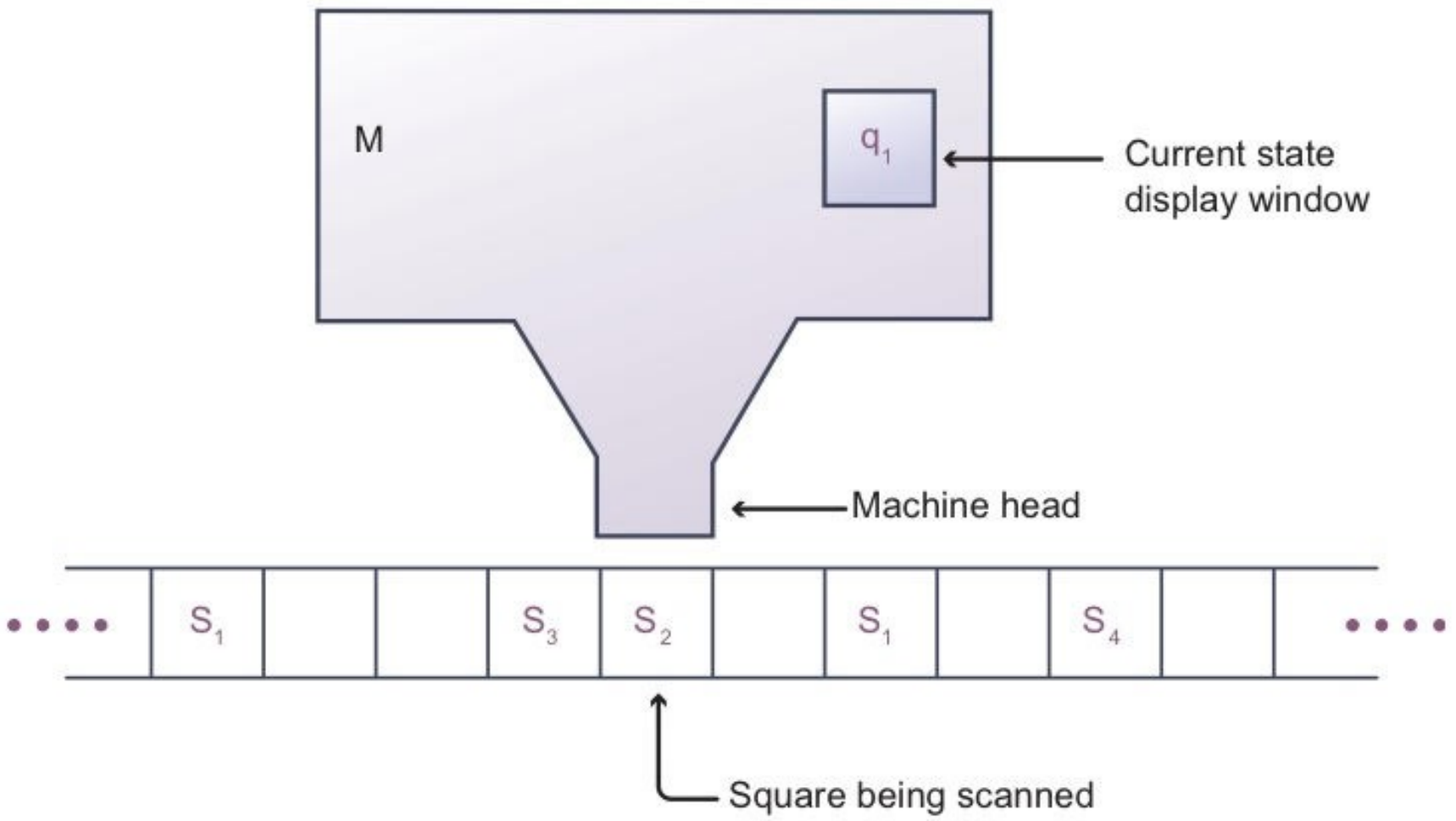
# Cross-maze


N
W
E
S
Responses of group 1
rats to obtain reward
Starting from S
Starting from N

# Turing Machines (1936, Turing)

- How to define an algorithm?
  - Suppose you want to prove that an algorithm for something exists, you just make it. A precise definition on what an algorithm is is not that important
  - But what if you want to show that there cannot exist an algorithm for a given problem? Then you need a precise definition
- Turing machines:
  - Tape, head, instructions
- In terms of CogSci, this was the first explicit model of information processing, which could, in theory be generalized to explain the mind (cybernetics)

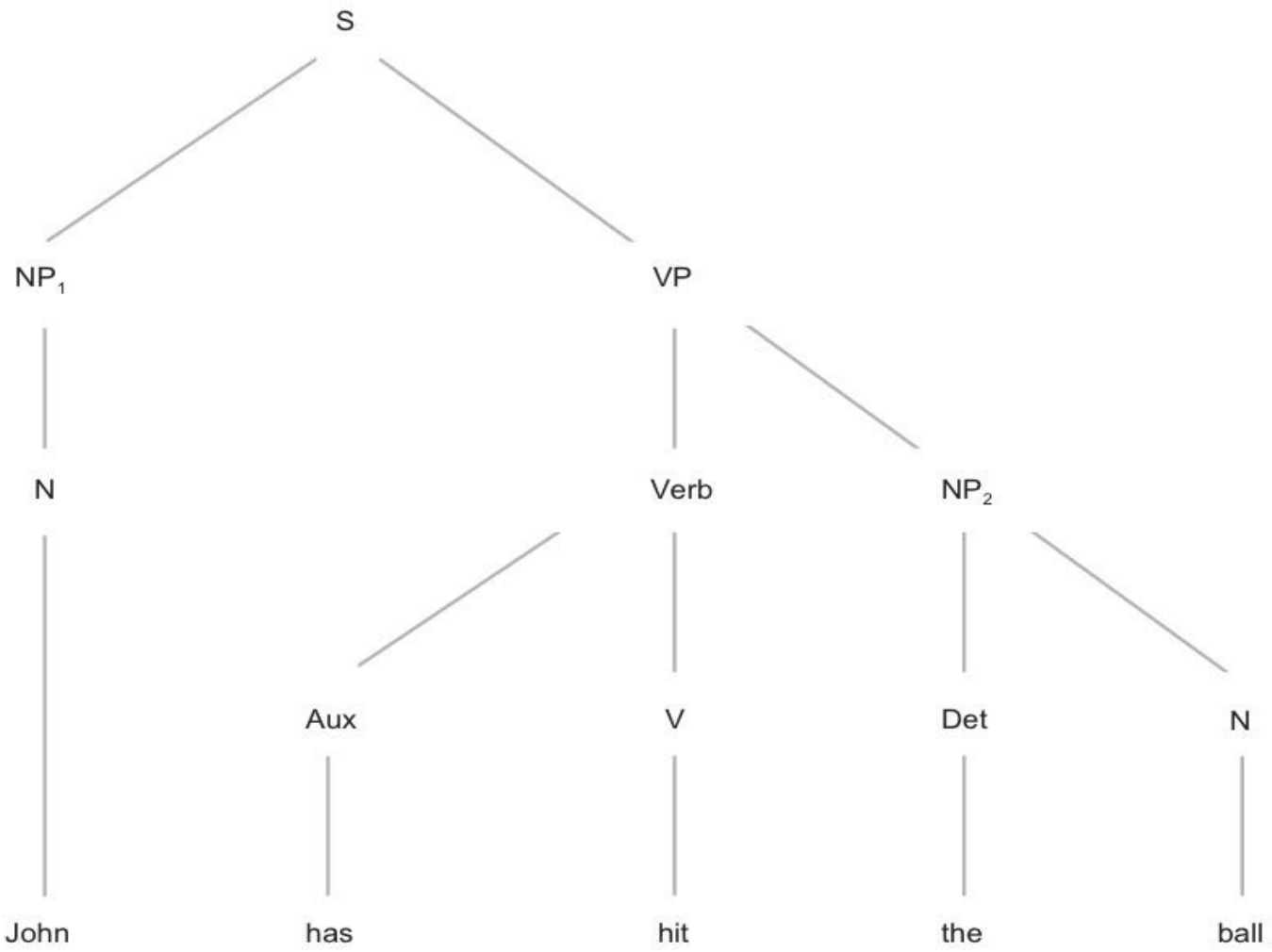
# Turing machine



# Structure of language (1957, Chomsky)

- Why do sentences have the structure they do?
  - Surface structure
  - Deep structure: trees
  - Transformations between valid sentences are algorithms
- Transformational grammars:
  - First idea: grammar use and transformations are a highly cognitive ability
  - Second: they are algorithmical

| | |
|---|---|
| S | Sentence |
| NP | Noun phrase |
| VP | Verb phrase |
| Verb | Aux + V |
| Aux | Auxiliary (e.g. “was” or “will”) |
| V | Verb |
| Det | Determiner (e.g. “the” or “a”) |
| N | Noun |



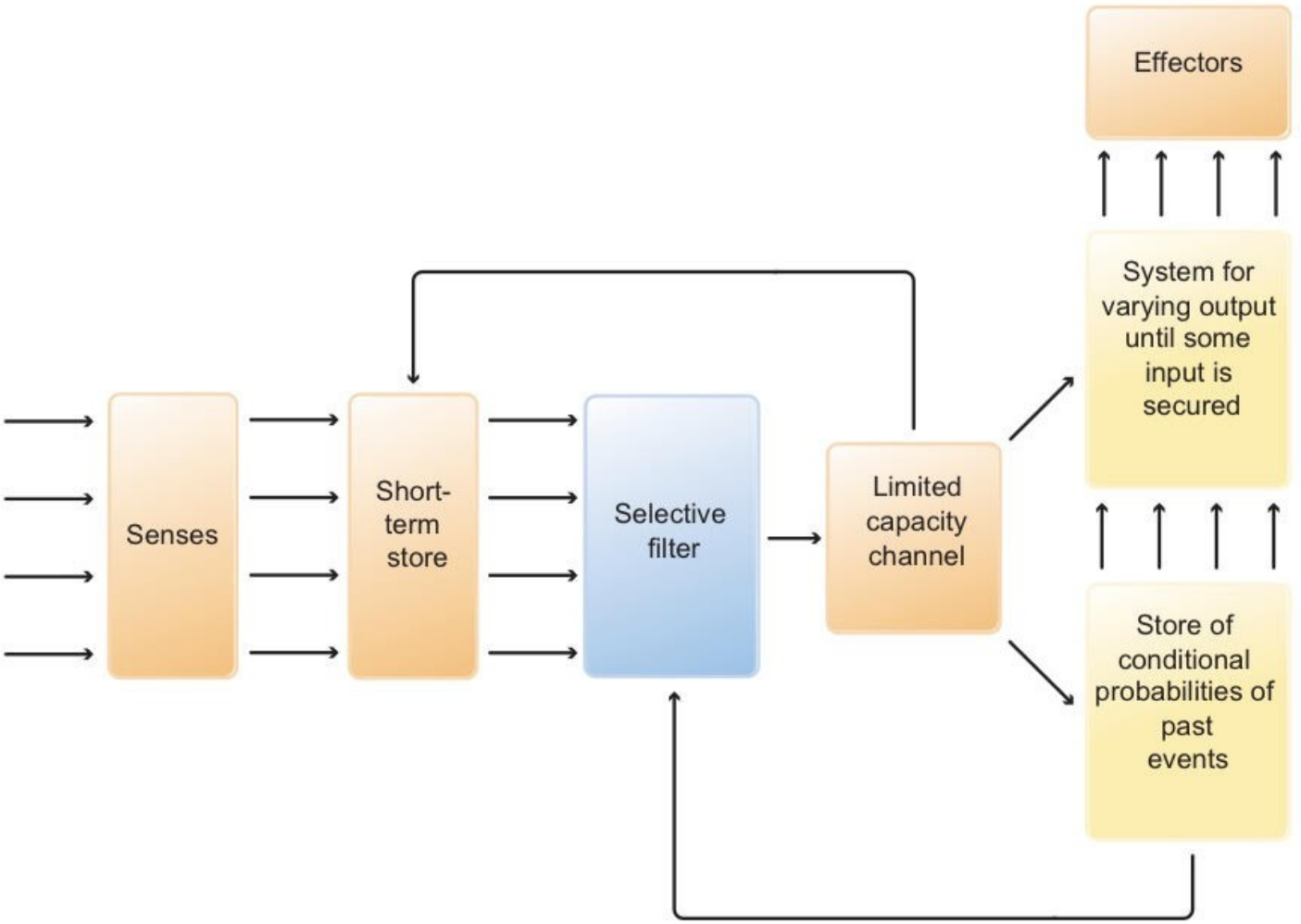
# How much information we can handle? (1956, Miller)

- Can ideas form information science be applied to study the mind?
  - Information channel
  - Perceptual systems seem to be also information channels...
- Experiment:
  - Subjects are given sequences of tones: A, C, A, C#, D,...
  - When given two tones, they never make a mistake
  - On average, mistakes start occuring after the seveth tone
  - This means that we have an auditory channel of 3 bits capacity

# Flow of information (1954, 1958 Broadbent)

- Some senses such as sight and taste touch are "selective" as such, but human auditory **attention** is selective:
  - In most circumstances, I can choose which voice do I listen to, even in crowds (cocktail party phenomenon)
  - Humans can only attend one information channel at a given time
- Broadbent developed the first ever model of attention
- Attention is currently under a (re)new(ed) focus due to its role in transformers
- General remark: If we can understand how information flows through a cognitive system, in theory, we understand it as a whole
- This is why Broadbent's work was also significant, since his flowchart became a paradigm on how cognitive science should work (in that era)

# Broadbent's model of selective attention



# Just for this lecture... homework

- Understand information-theoretic concepts of entropy, crossentropy and KL-divergence
- Youtube: "Aurelien Geron Crossentropy"
  - 10:41 min video, but you will need to pause it and write it out... it should take you around 1h-1.5h to fully understand it. **Do it properly**, give it all the time it takes and do not rush!
  - https://www.youtube.com/watch?v=ErfnhcEV1O8