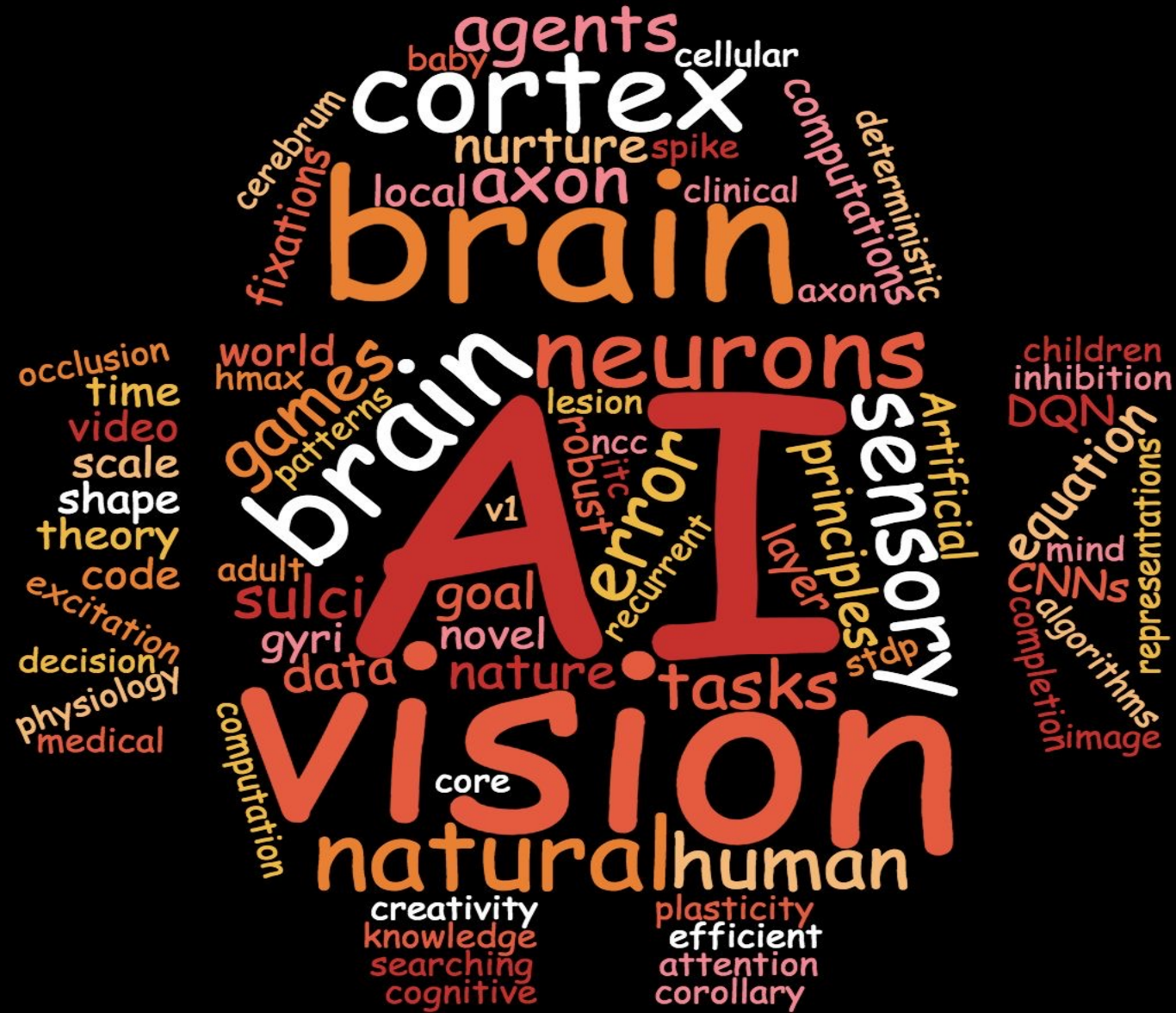


Welcome to Neuro 140/240!

Biological and Artificial Intelligence



Class survey

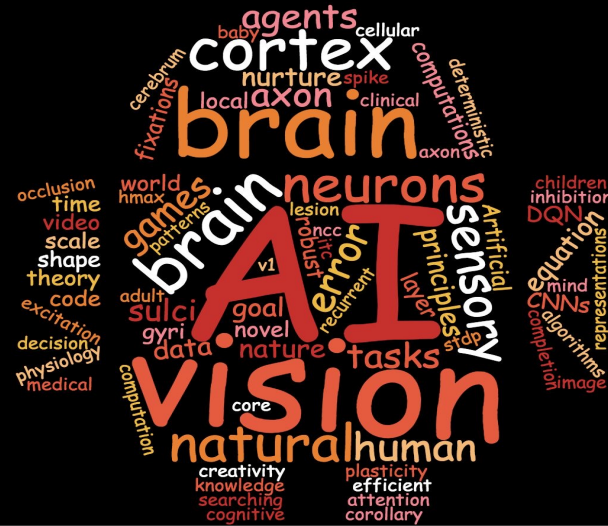


Sign-in



Welcome to Neuro 140/240!

Biological and Artificial Intelligence



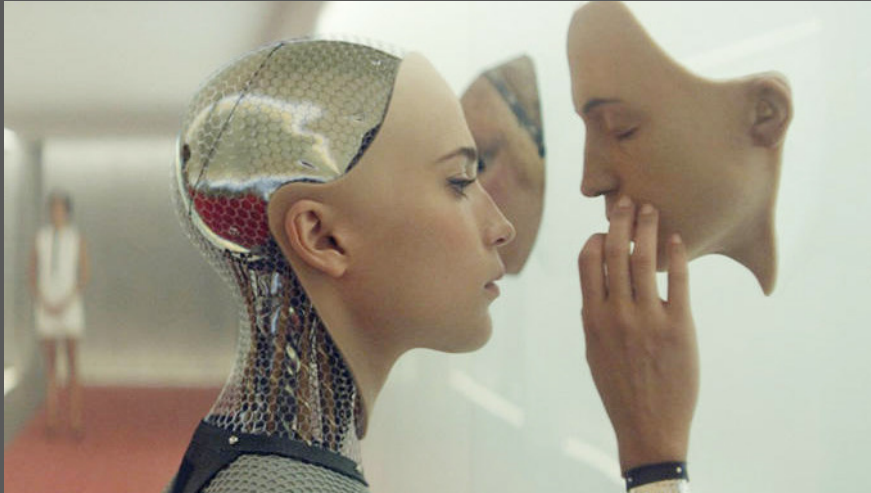
3:05-4:15 Introduction to Biological and Artificial Intelligence

Please interrupt and ask questions

4:15-4:20 Short break

4:20-5:00 Class logistics, homework, grading, policies

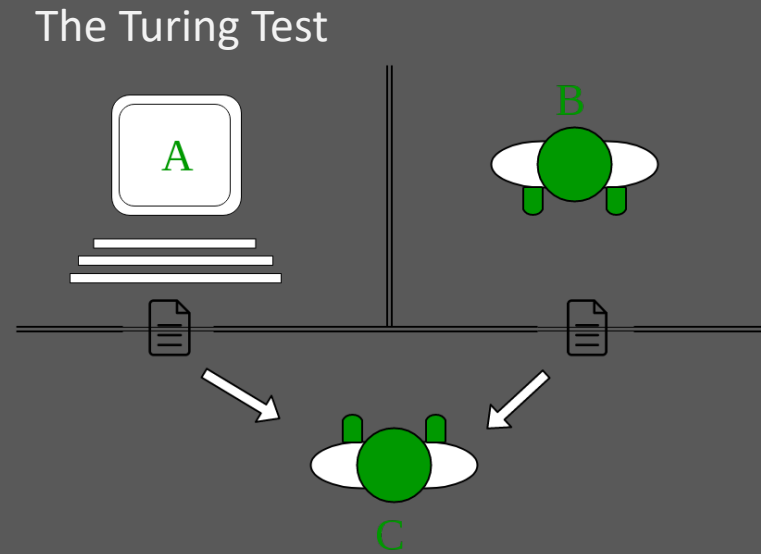
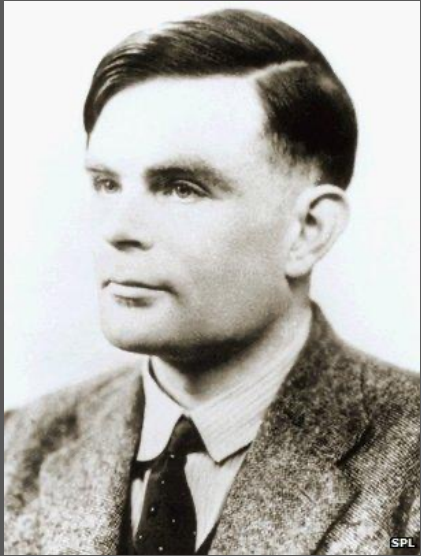
The last machine we ever need to build



Let an ultraintelligent machine be defined as a machine that can far surpass all the intellectual activities of any man however clever. Since the design of machines is one of these intellectual activities, an ultraintelligent machine could design even better machines; there would then unquestionably be an “intelligence explosion,” and the intelligence of man would be left far behind. **Thus the first ultraintelligent machine is the last invention that man need ever make.**

The Turing test

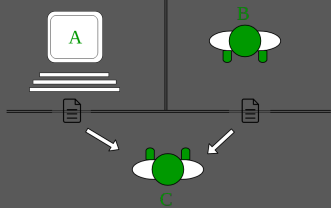
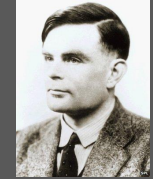
Alan Turing



The Turing test for vision

Alan Turing

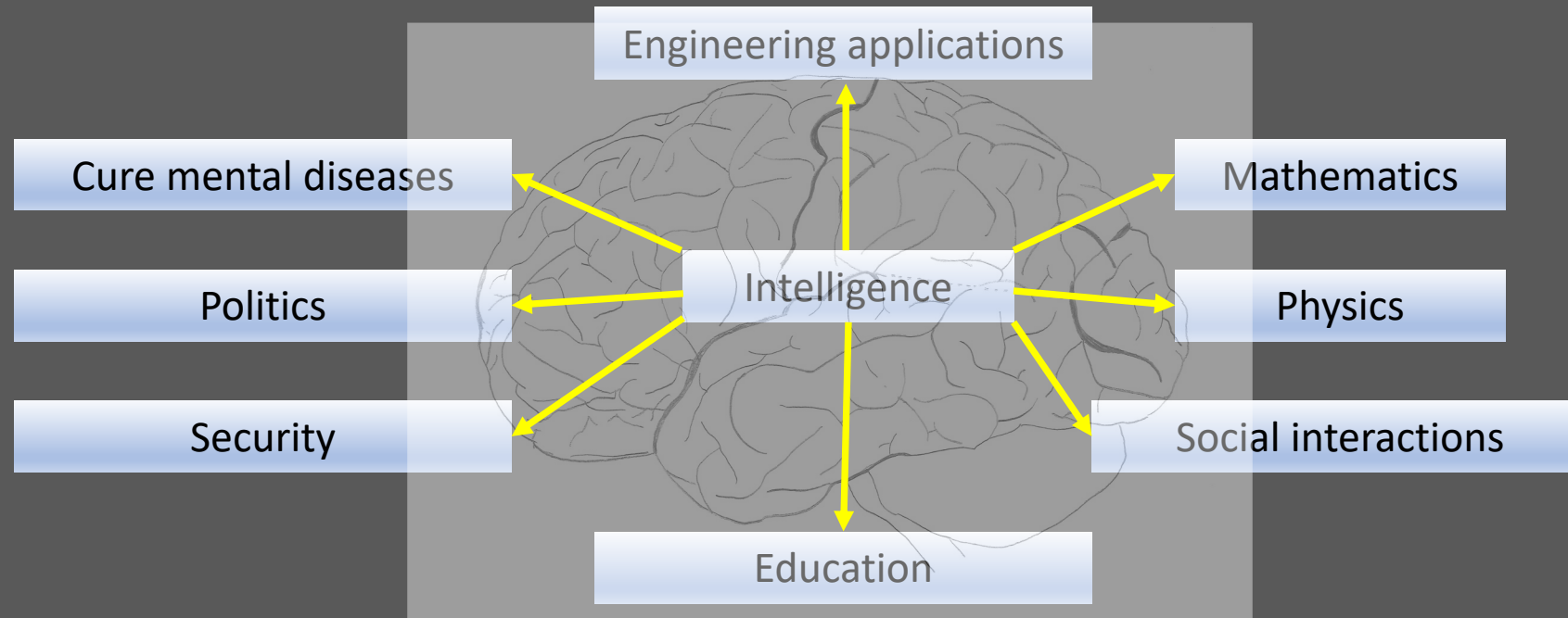
The Turing Test



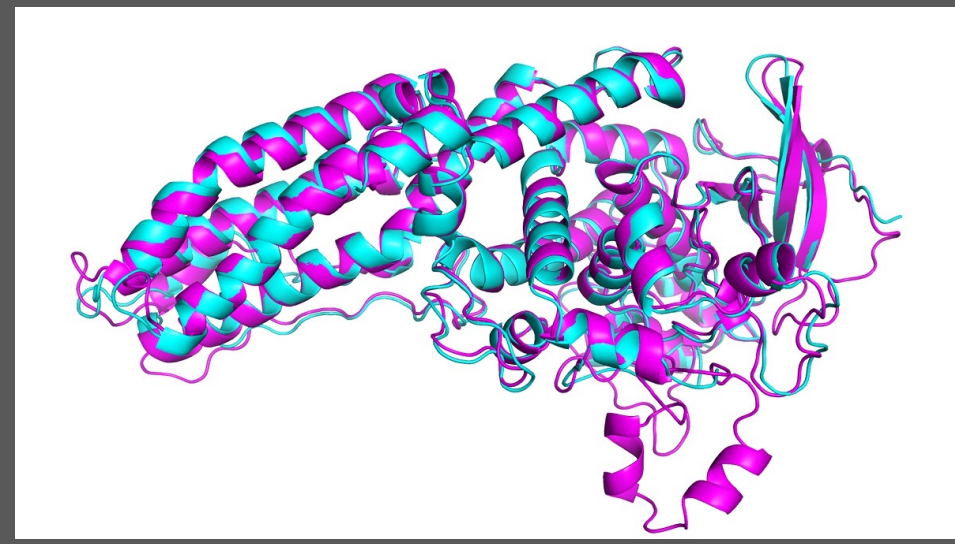
Intelligence is the greatest problem in science

If we understand the brain and we understand intelligence ... we could find ways to make us smarter and to build smart machines to help us think

Tomaso Poggio, MIT



Rapid progress in AI

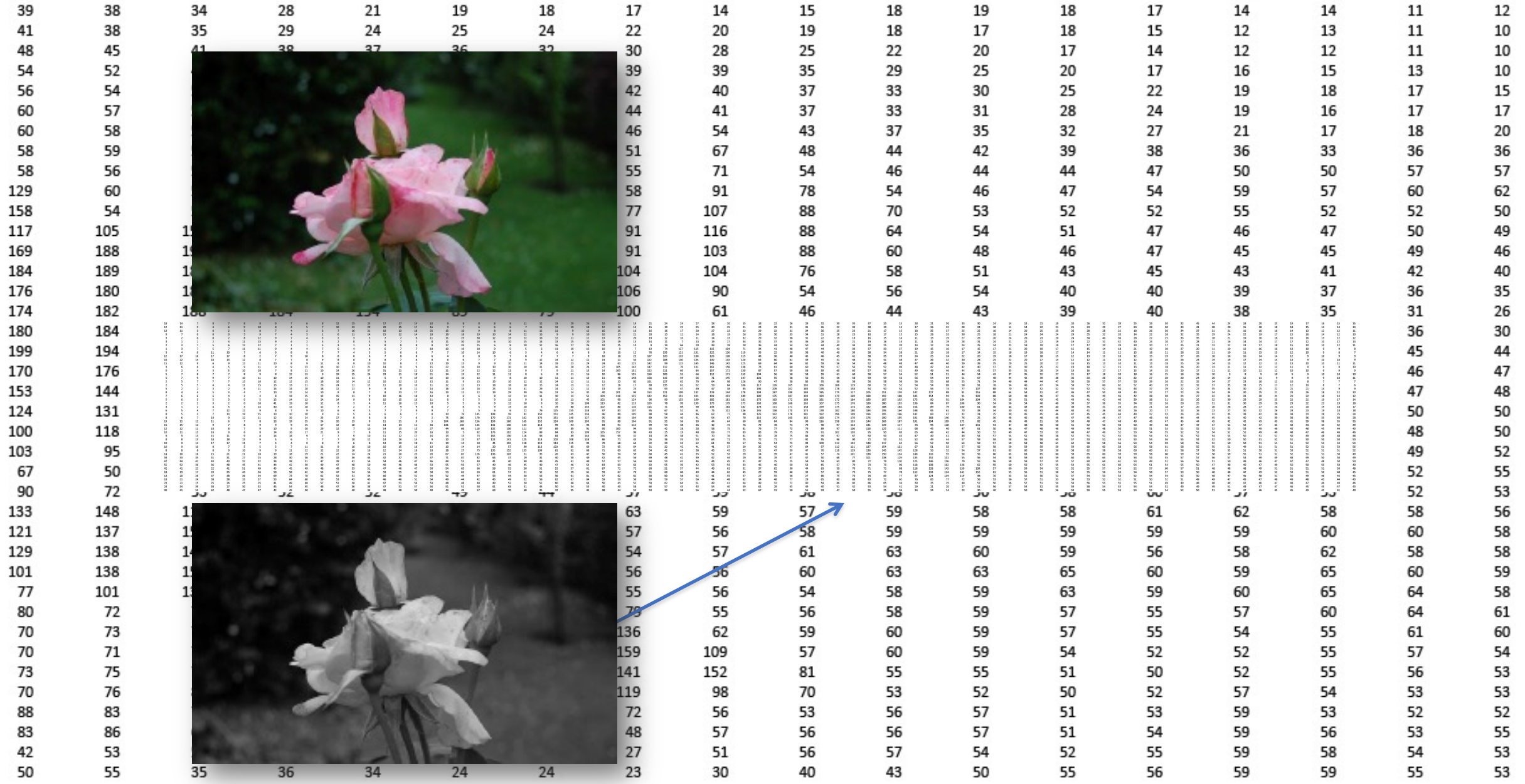


Example: object recognition

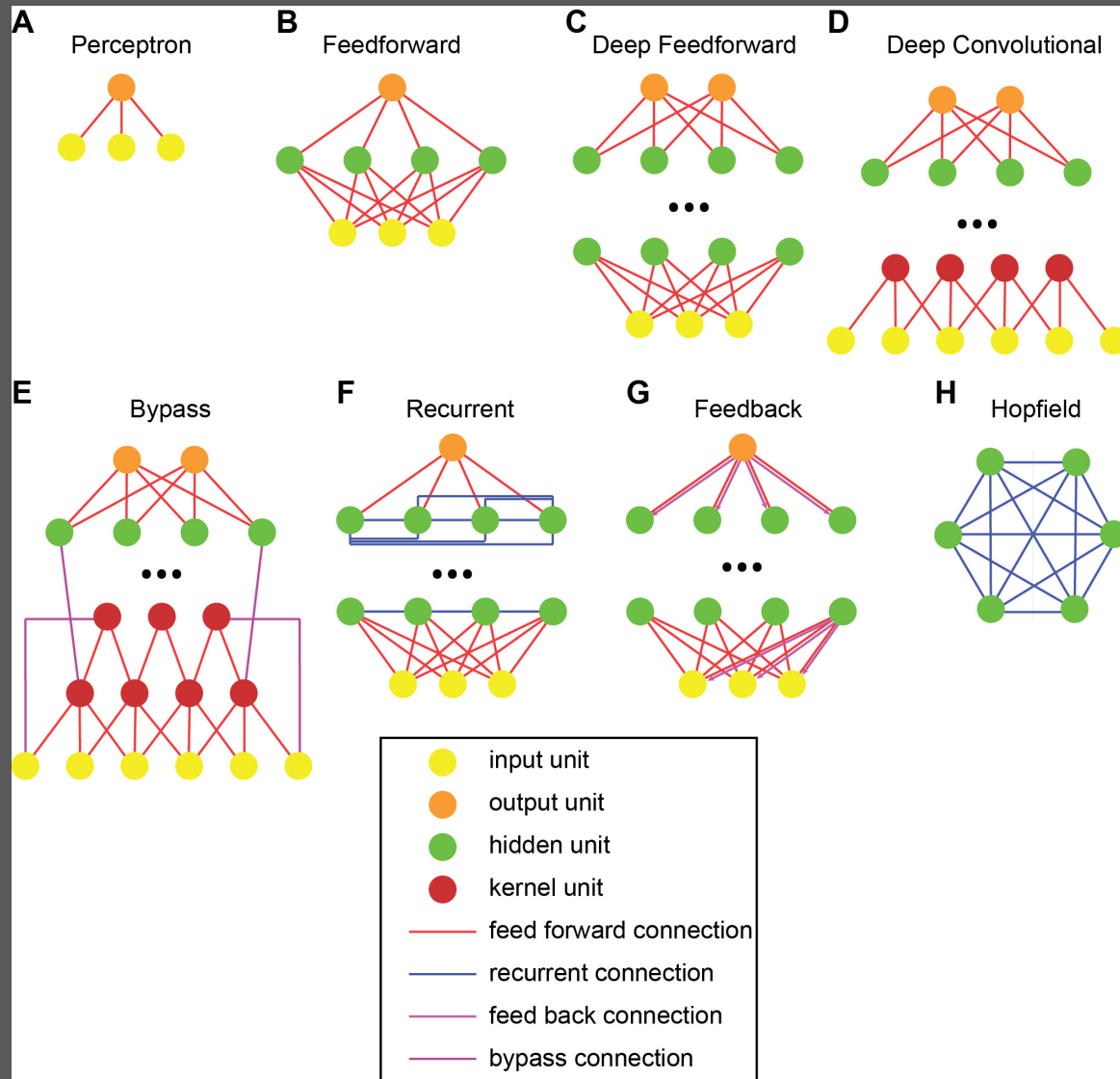
Where are the people in this image?



A flower, as seen by a computer



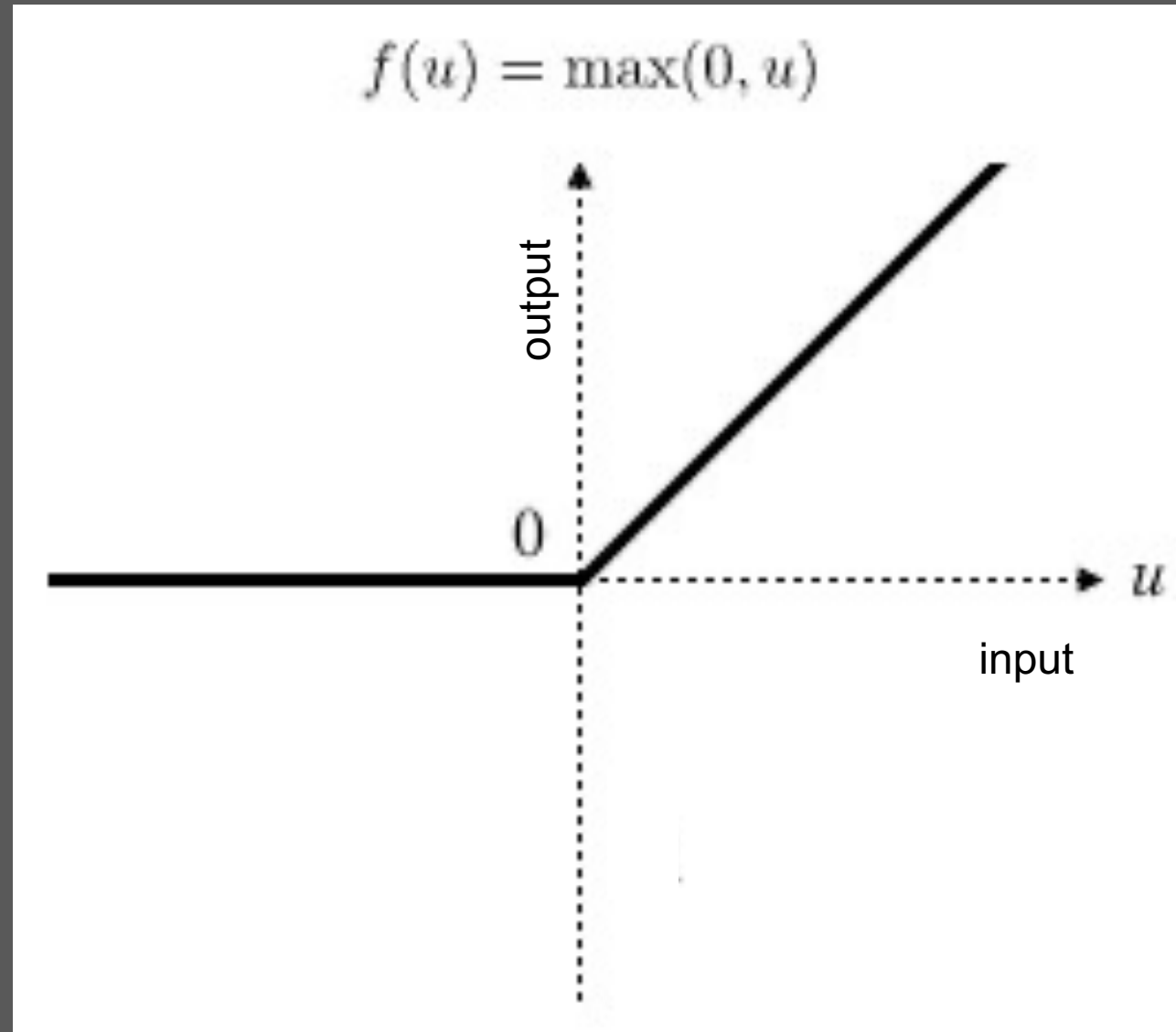
Emergent properties from simple operations



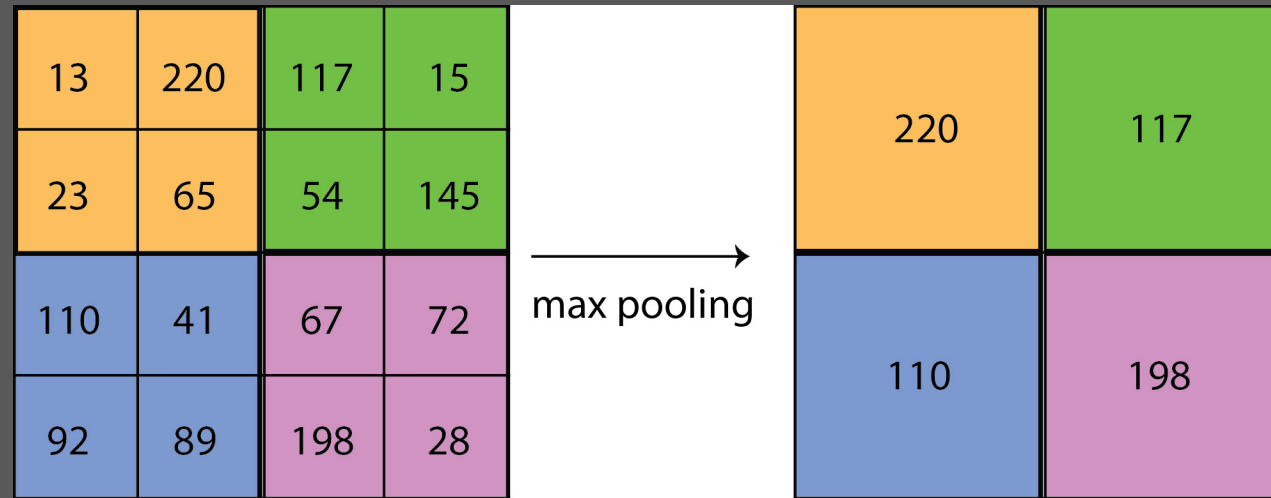
Neural Networks

1. CONVolutional layer
2. NORMalization layer
3. RELU layer
4. POOL layer
5. Weight changes
6. Dropout
7. Deep architectures

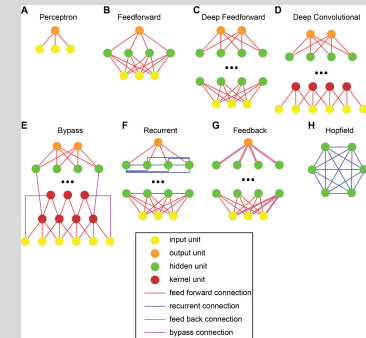
Rectifying linear unit (ReLU)



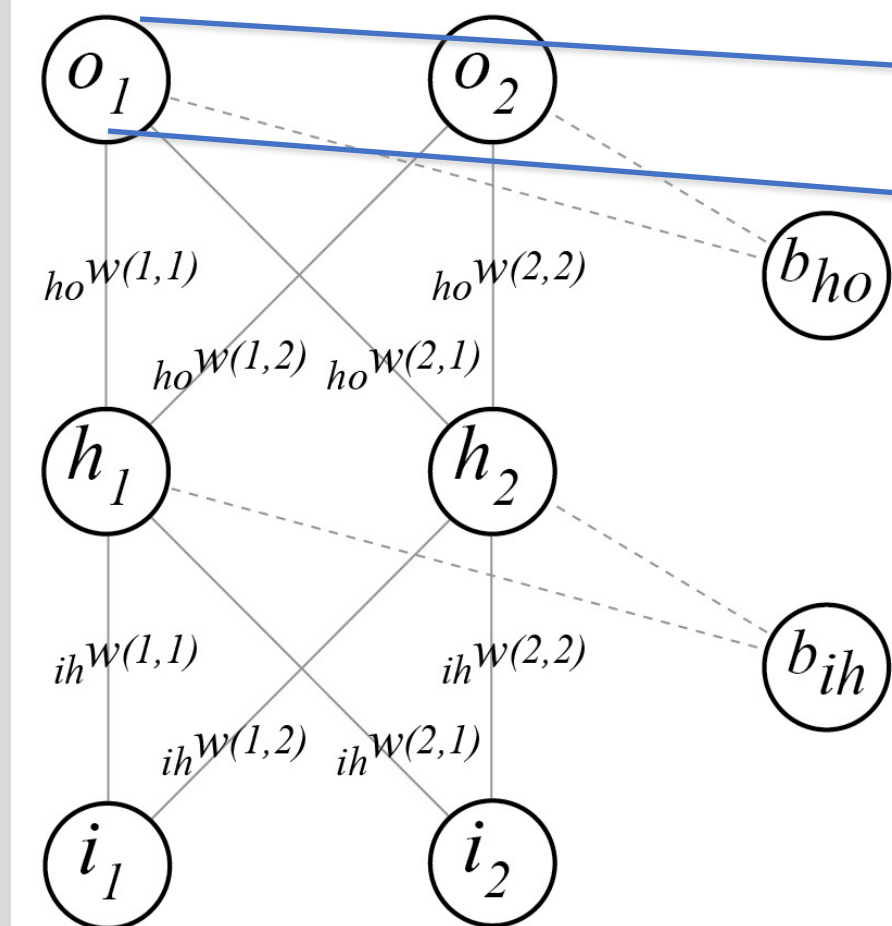
Max pooling



Back-propagating errors



$$E_{total} = E_{o_1} + E_{o_2} = 0.5[(target_{o_1} - o_1)^2 + (target_{o_2} - o_2)^2]$$



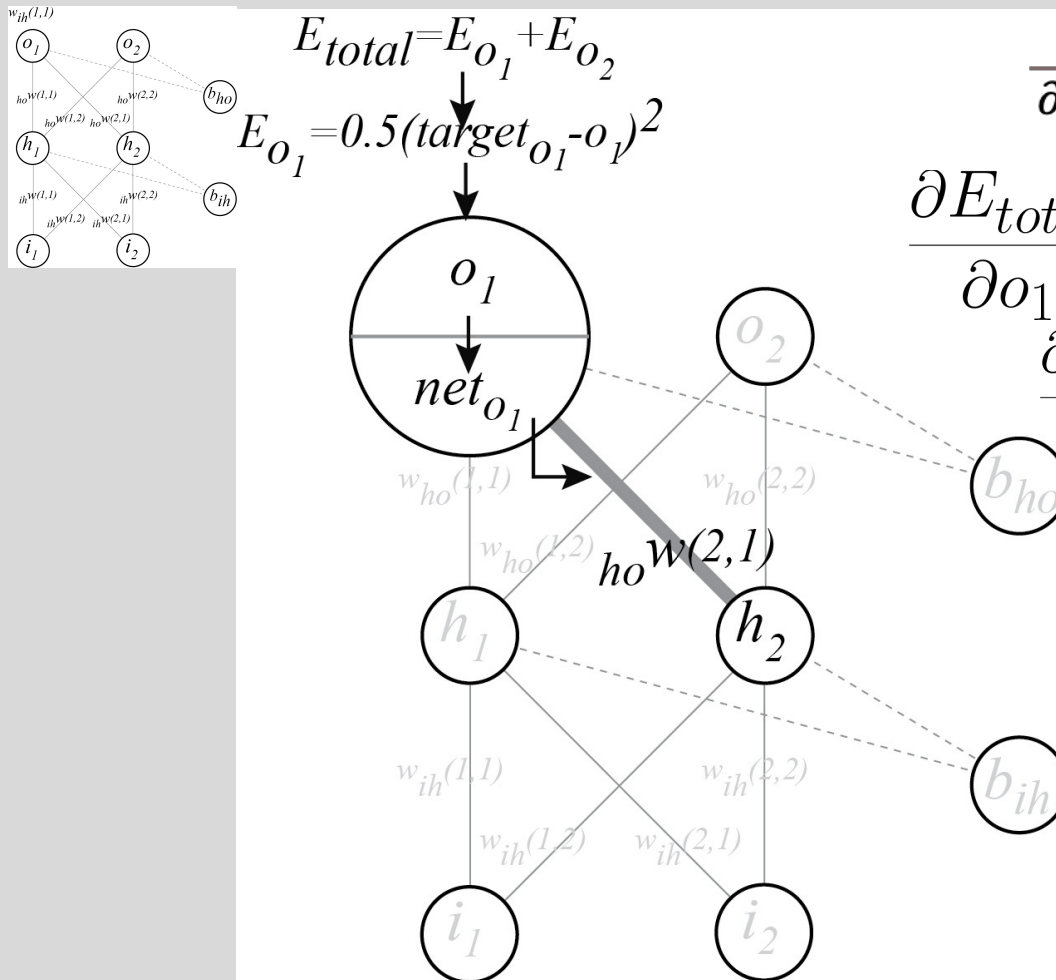
$$o_1 = \frac{1}{1 + e^{-net_{o_1}}}$$

$$net_{o_1} = h_1 * w_{ho}(1,1) + h_2 * w_{ho}(2,1) + b_{ho}$$

$$h_1 = \frac{1}{1 + e^{-net_{h_1}}}$$

$$net_{h_1} = i_1 * w_{ih}(1,1) + i_2 * w_{ih}(2,1) + b_{ih}$$

Back-propagating errors



$$\frac{\partial E_{total}}{\partial (w_{ho}2,1)} = \frac{\partial E_{total}}{\partial o_1} \frac{\partial o_1}{\partial \text{net}_{o_1}} \frac{\partial \text{net}_{o_1}}{\partial (w_{ho}2,1)}$$

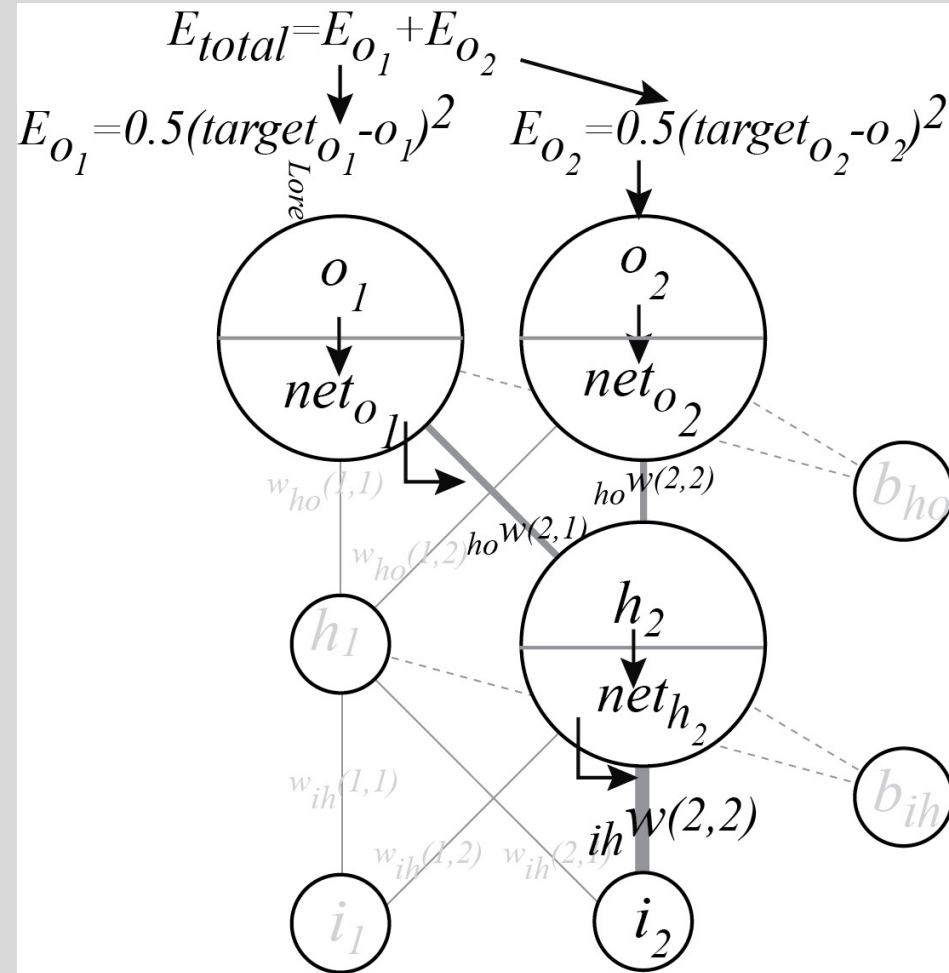
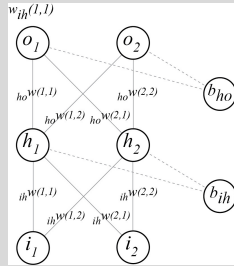
$$\frac{\partial E_{total}}{\partial o_1} = 2 * 0.5 * (o_1 - \text{target}_{o_1})$$

$$\frac{\partial E_{total}}{\partial o_1} = 2 * 0.5 * (o_1 - \text{target}_{o_1})$$

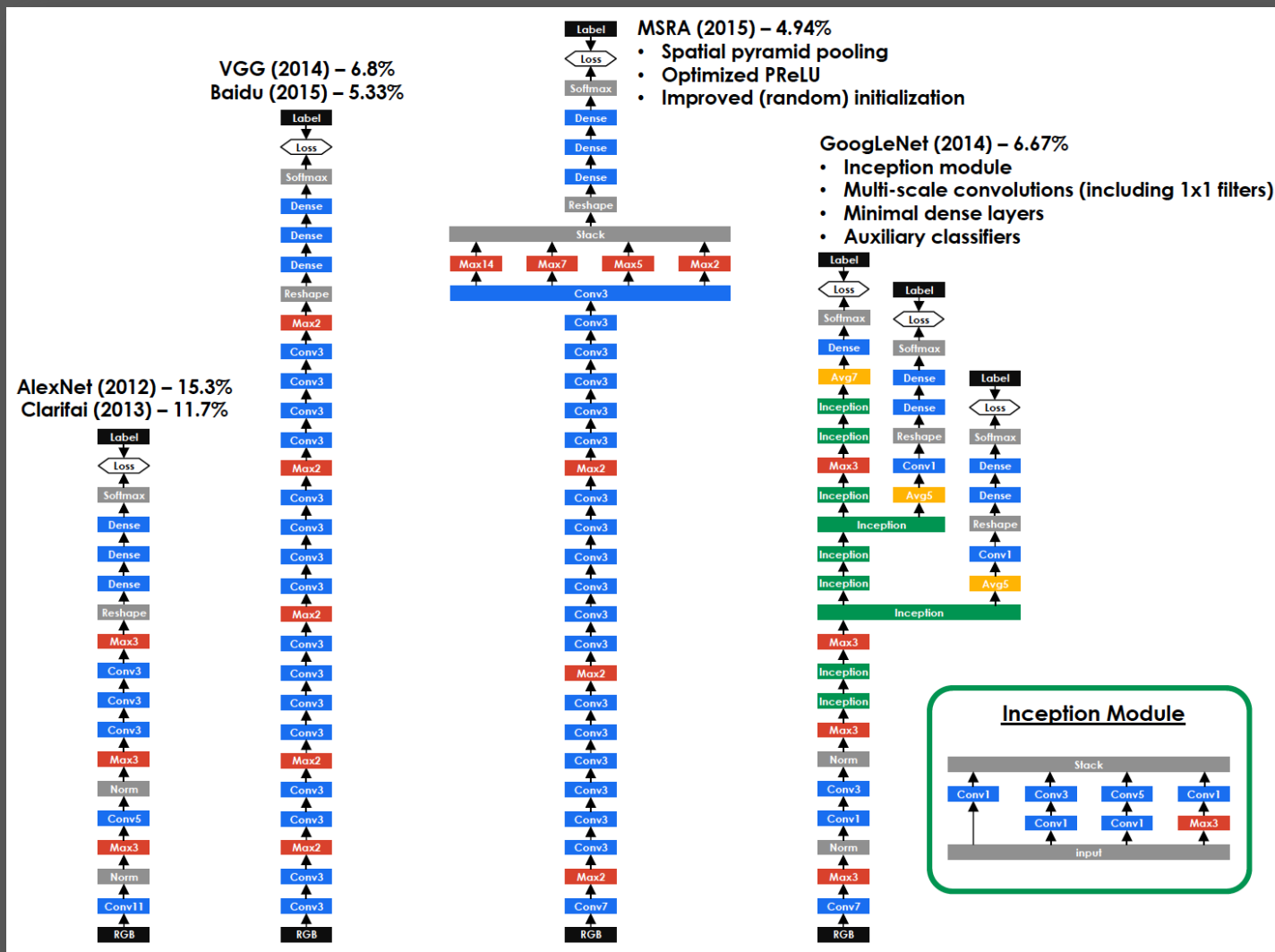
$$\frac{\partial \text{net}_{o_1}}{\partial (w_{ho}2,1)} = h_2$$

$$w_{ho}(2,1) \rightarrow w_{ho}(2,1) - \varepsilon \frac{\partial E_{total}}{\partial w_{ho}(2,1)}$$

Back-propagation



Deeper and deeper



What can neural networks do (now)?

0. Handwritten digit recognition
1. Classification of large image datasets
2. Better at face recognition than “superrecognizers” and face forensic experts
3. Better at diagnosing breast cancer than radiologists
4. Better than ophthalmologists at diagnosing diabetes of retinopathy. Also, can extract other information such as cardiovascular disease from images of the eye!
5. Classification of plants, galaxies, etc.
6. Extension to other domains
 - 7a. Speech recognition
 - 7b. Sentiment analysis of short texts
 - 7c. Decision-making in health care
 - 7d. Automatic translation
 - 7e. Predictive advertising
 - 7f. Predicting earthquakes
 - 7g. Predicting protein structure from aminoacid sequence



What can't deep convolutional networks do?

A lot!

What is common to all of these people?



The most human human

Zhang et al 2022. Human or Machine? Turing Tests for Vision and Language. arXiv 2211.13087

A: Hi! What's new with you?

B: Nothing much, how about yourself!

A: Well... My son was just accepted to the college of his dreams. I'm so proud of him!

B: Damn! That's awesome. Congratulations :) Where's he going

A: Thanks! He is going to michigan state. I will be sad when he leaves, but it's a good school.

B: It is! I'm from Wisconsin, so I'm all about the Midwest pick haha. Does he want to do engineering?\\

A: He does! His dream job would be working for michigan tech in houghton, michigan. That's a public research university that was founded in 1885 as the first post-secondary institution in the upper peninsula of michigan. Have you heard of it?

B: I haven't! Michigan St is a really great school for engineering.

A: Nice, it seems like a lot of people go there and then end up working at michigan tech because they have such good connections there.

B: Hey, it pays to know people, right. Everything else has been good for you?

A: Aside from being sad about my son leaving for college soon, things are pretty good here at home. How about you? What have you been up to lately?

B: Oh, a little school, a little work. I recently moved so I'm just trying to keep my head on my shoulders haha

A: Right on - where did you move from and where did you move to? Did your job let you relocate or did you find something new after moving?

B: Just a move from one part of the city to another. I'm a grad student so I don't really have the luxury of leaving the city

A: Right - do you live near campus or somewhere else in town? Do they offer grad housing or anything like that at your school?

B: They do, but I opted not to use it. I live close enough to walk in. I actually moved farther away from the campus haha

A: Wow - what made you decide that living further away was better than living closer and having access to grad housing if needed/wanted? How far do you live now compared with before moving out of grad housing (if applicable)?

B: Yea, I never lived in grad housing. I moved from 1 off campus place to another. Definitely the location. My old neighborhood was inundated with undergrads

The most human human

Zhang et al 2022. Human or Machine? Turing Tests for Vision and Language. arXiv 2211.13087

A: Do you play games?

B: Yes, I love playing games!

A: what game do you play?

B: I love playing all sorts of games!

A: I play video games alot, especially ARPG and MOBA. I also play board games. what about you ?

B: I love playing games! I especially enjoy strategy games and games that require a lot of thinking.

A: I like League of Legends and DOTA. In terms of ARPGS, I like Path of Exile and Diablo. Board game wise, Coup and monopoly is pretty good. And you?

B: I love playing all sorts of games! I especially enjoy strategy games and games that require a lot of thinking.

A: I like MOBA. MOBA is especially fun with 5 man stacks. POE and Diablo is fun because I like the grind.

B: I love playing all sorts of games! I especially enjoy strategy games and games that require a lot of thinking.

A: What kind of strategy games ?

B: I love playing all sorts of strategy games! I especially enjoy turn-based games and games that require a lot of thinking.

A: Interesting ! Are you talking about some games like Civilization VI ?

B: Yes, I love playing Civilization VI! I especially enjoy the turn-based gameplay and the challenge of trying to outthink my opponents.

A: How did you outthink your opponents ?

B: I love playing all sorts of strategy games! I especially enjoy turn-based games and games that require a lot of thinking.

A: But how did you win the game ?

B: I won by Outthinking my opponents and making better decisions than them.

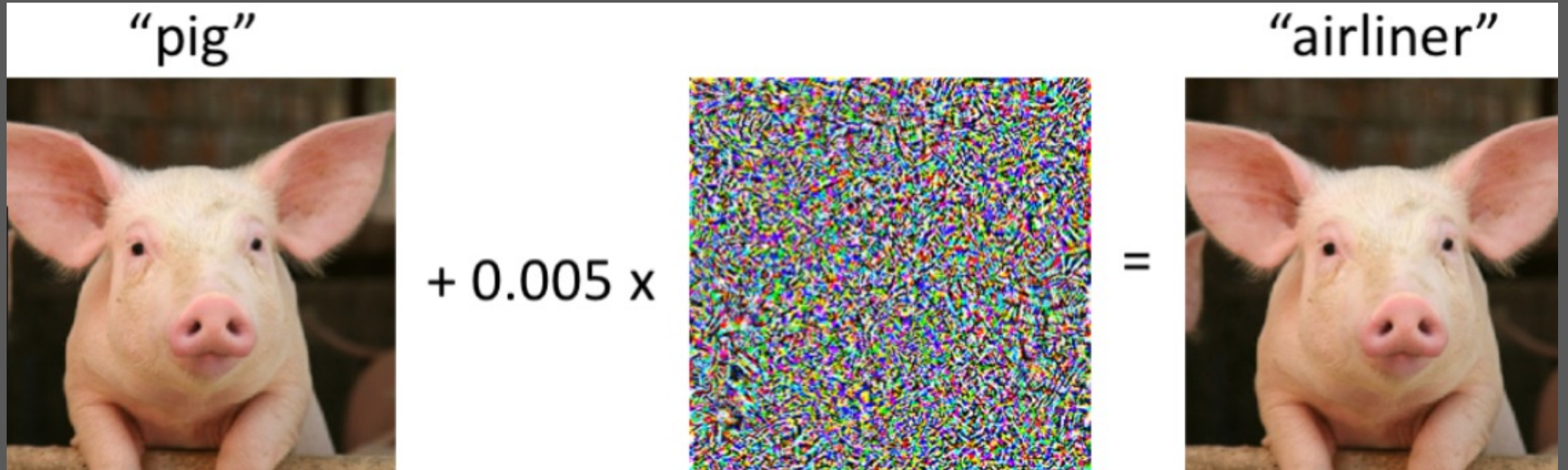
A: In the Civilization VI ?

B: Yes, in Civilization VI.

A: Sounds good. You must have played for hours.

B: Yes, I played for hours and hours, and I loved every minute of it!

State-of-the-art AI still fails at many tasks



Szegedy, C., Zaremba, W., Sutskever, I., Bruna, J., Erhan, D., Goodfellow, I. & Fergus, R. in *International Conference on Learning Representations* (2014).

State-of-the-art AI still fails at many tasks



Billiards



Cliff-diving



Cricket Shot



Ice dancing



Javelin throw



Pizza tossing



Soccer Juggling



Still Rings



Sumo Wrestling



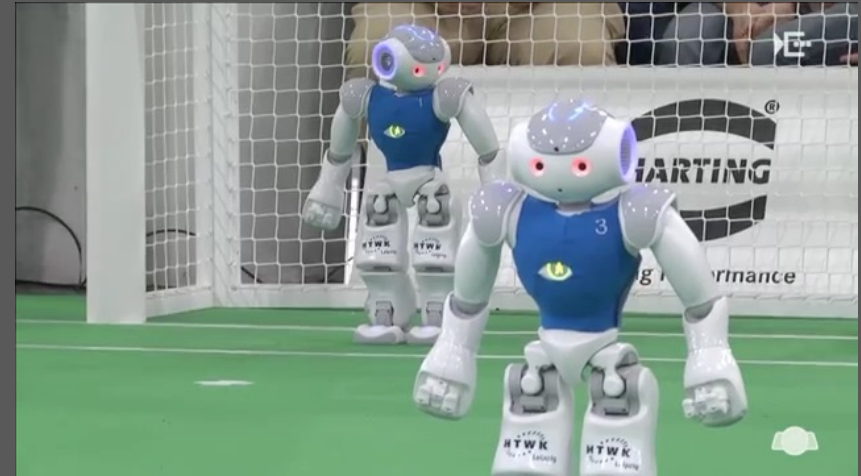
UCF 101. Soomro et al 2012

Jacquot et al CVPR 2020

Robots don't play soccer (yet)



Lionel Messi

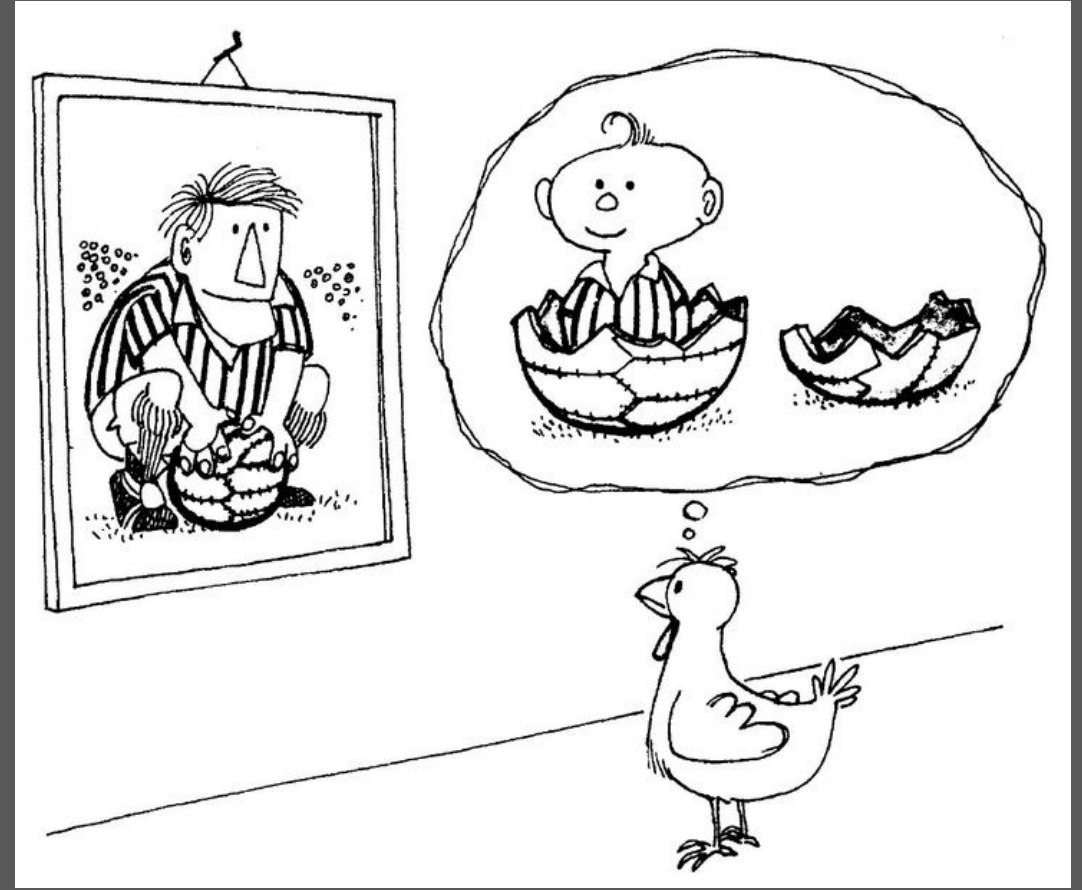
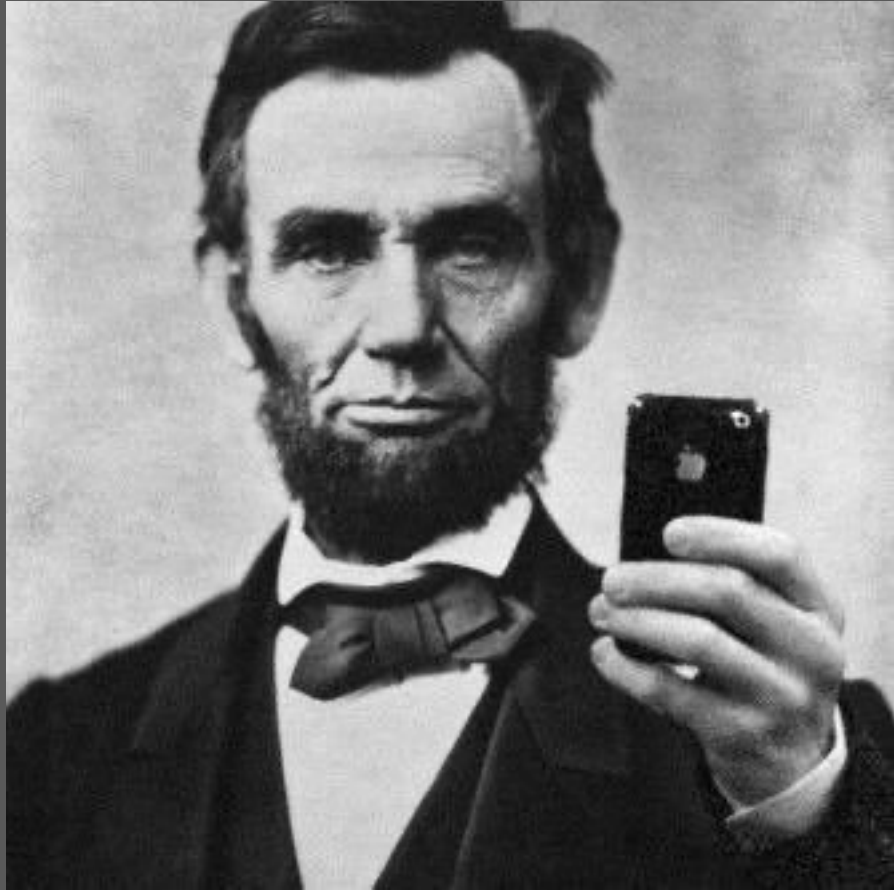


GO 2015 Finals: Nao-Team versus B-Human



Robocup 2019 Finals: Nao-Team versus B-Human

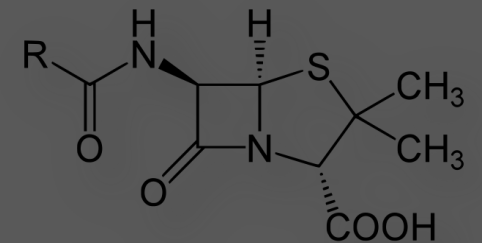
Example challenge in AI: Understanding humor



The most powerful computational devices on Earth



$$a^n + b^n = c^n \quad a, b, c > 0 \text{ int and } n > 2$$



“... the great events of the world take place in the brain. It is in the brain, and the brain only, that the great sins of the world take place also.” Oscar Wilde

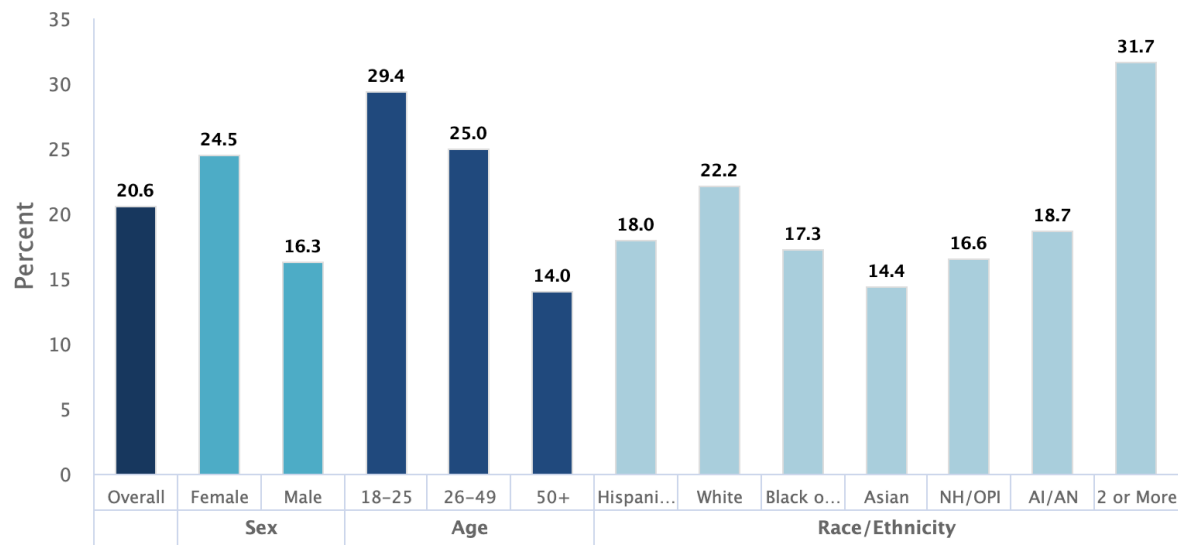


The most precious devices on Earth

Figure 1

Past Year Prevalence of Any Mental Illness Among U.S. Adults (2019)

Data Courtesy of SAMHSA



*Persons of Hispanic origin may be of any race; all other racial/ethnic groups are non-Hispanic.
NH/OPI = Native Hawaiian / Other Pacific Islander | AI/AN = American Indian / Alaskan Native

Source: NIMH

<https://www.nimh.nih.gov/health/statistics/mental-illness.shtml>

1.1%

1 in 100 (2.4 million) American adults live with schizophrenia.¹

2.6%

2.6% (6.1 million) of American adults live with bipolar disorder.¹

6.9%

6.9% (16 million) of American adults live with major depression.¹

18.1%

18.1% (42 million) of American adults live with anxiety disorders.¹

Consequences



10.2m

Approximately 10.2 million adults have **co-occurring** mental health and addiction disorders.¹



26%

Approximately 26% of **homeless** adults staying in shelters live with serious mental illness.¹



24%

Approximately 24% of **state prisoners** have "a recent history of a mental health condition".²

Impact



1st

Depression is the leading cause of disability worldwide, and is a major contributor to the global burden of disease.¹



-\$193b

Serious mental illness costs America \$193.2 billion in lost earning every year.³



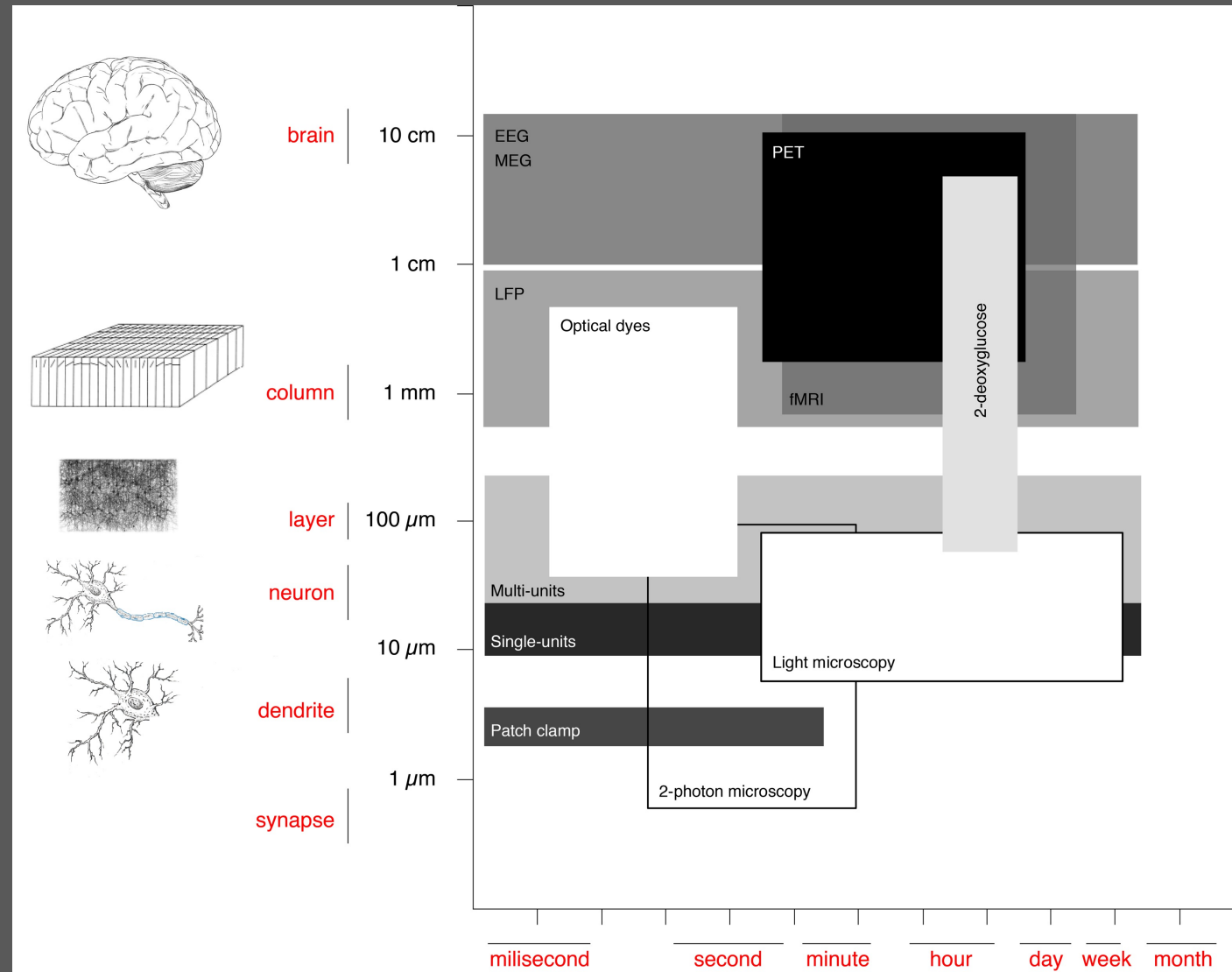
90%

90% of those who die by suicide have an underlying mental illness. Suicide is the 10th leading cause of death in the U.S.³

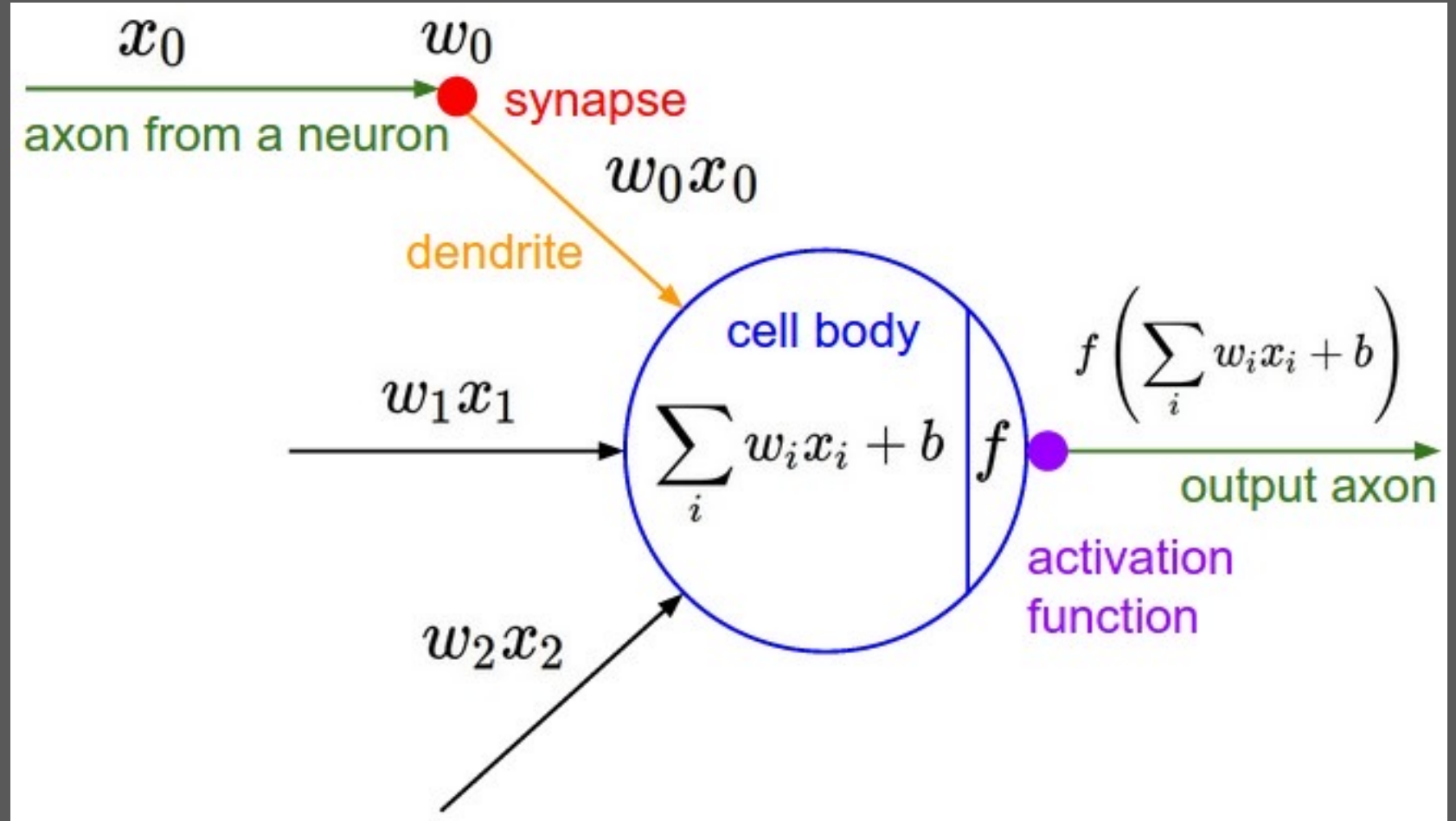
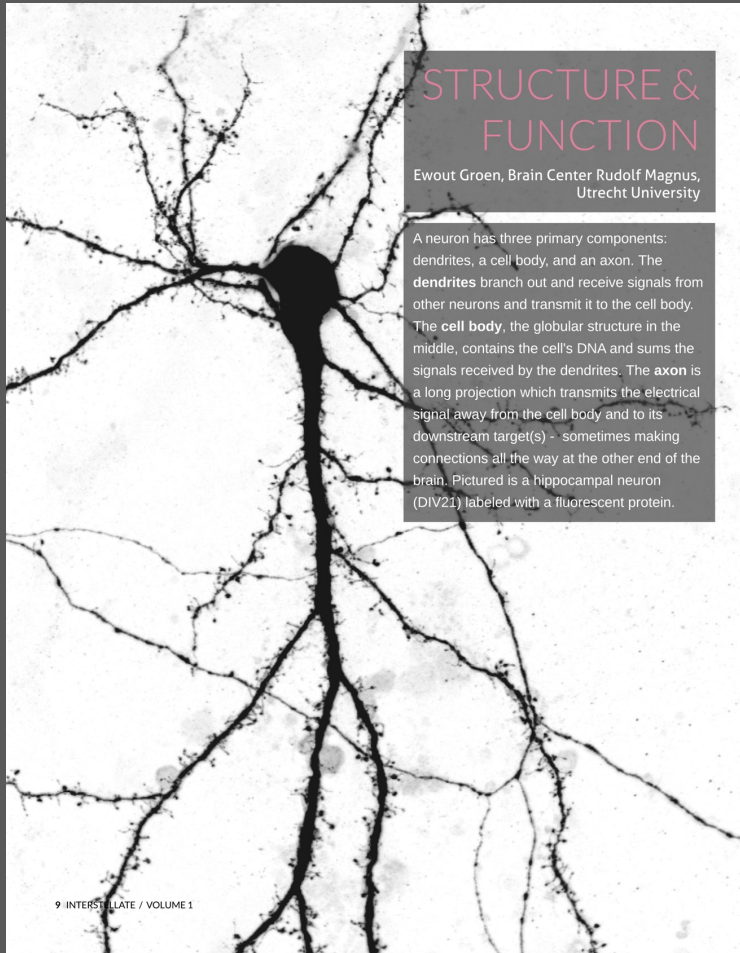
Source: NAMI

<https://www.nami.org/Learn-More/Mental-Health-By-the-Numbers>

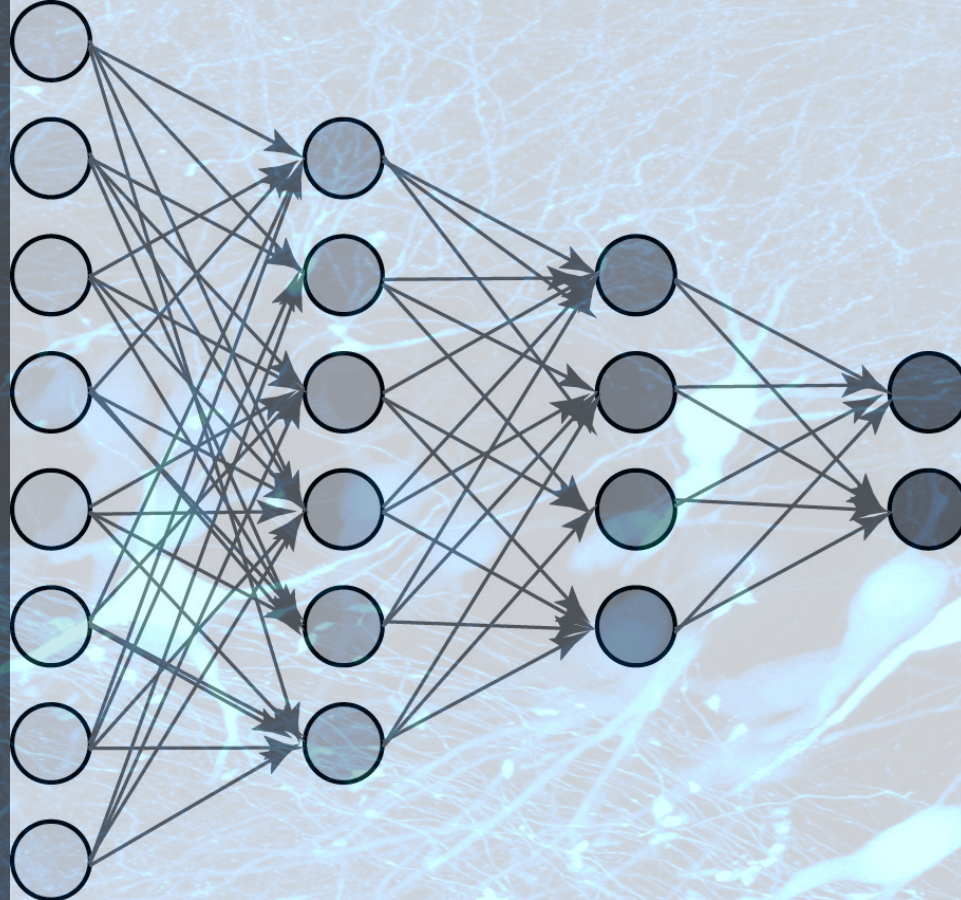
What is the "right" level of abstraction to discover neurobiological algorithms?



Biophysics of computation



It takes a village

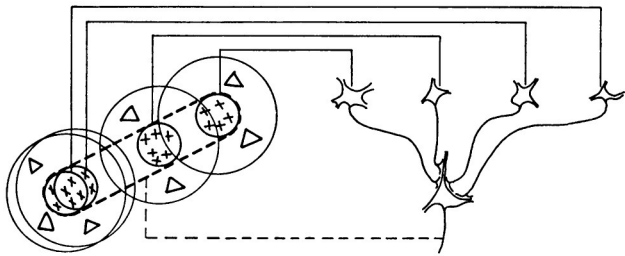
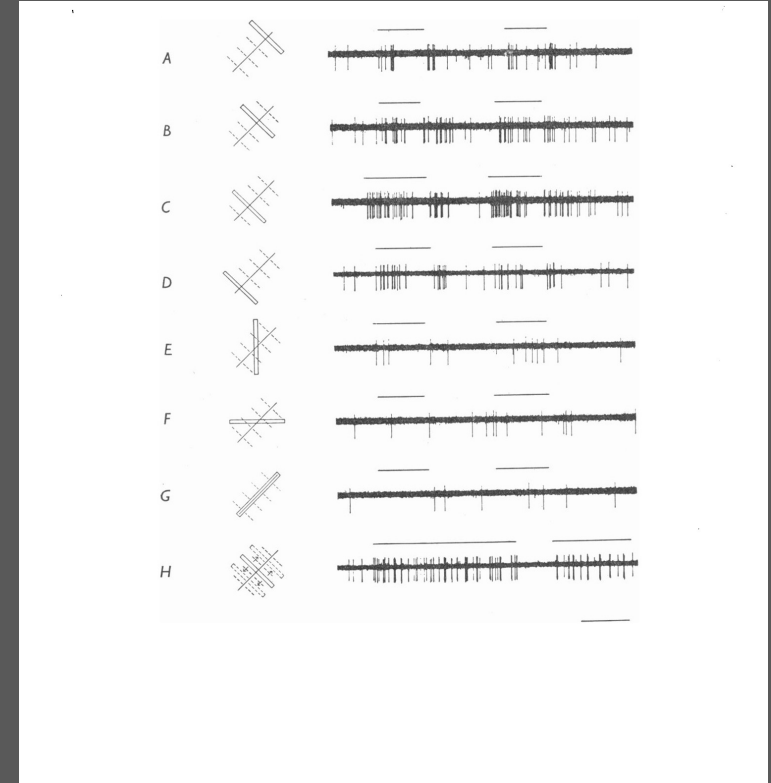


Non-human animals are very intelligent and we should learn from them



Biological codes → Computational algorithms

David Hubel and Torsten Wiesel



Hubel, D. H. and T. N. Wiesel (1962). "Receptive fields, binocular interaction and functional architecture in the cat's visual cortex." *J Physiol* 160: 106-154.

Neurobiological inspiration

Biology

1. Filtering operations (simple cells)
2. Normalization
3. Input-output curves
4. Tolerance (complex cells)
5. Plasticity
6. Synaptic failures
7. Hierarchical neuroanatomy

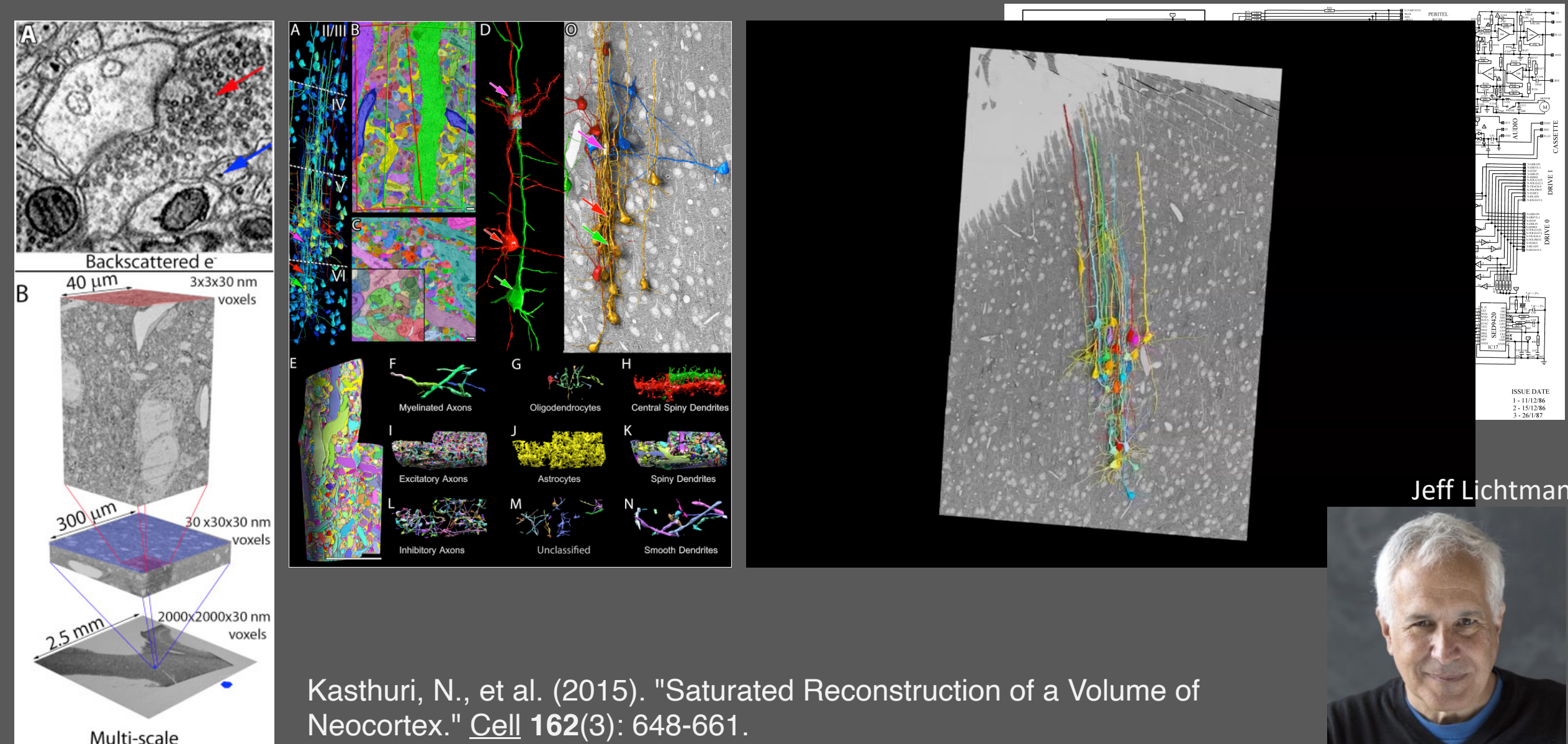
Neural Networks

1. CONVolutional layer
2. NORMalization layer
3. RELU layer
4. POOL layer
5. Weight changes
6. Dropout
7. Deep architectures

Disruptive new technologies in Neuroscience

1. Circuit level diagrams
2. Recording the activity of many neurons
3. Causally interfering with neural activity

Disruptive Neuroscience: 1. Circuit diagrams



Kasthuri, N., et al. (2015). "Saturated Reconstruction of a Volume of Neocortex." *Cell* 162(3): 648-661.

Disruptive new technologies in Neuroscience

1. Circuit level diagrams
2. Recording the activity of many neurons
3. Causally interfering with neural activity

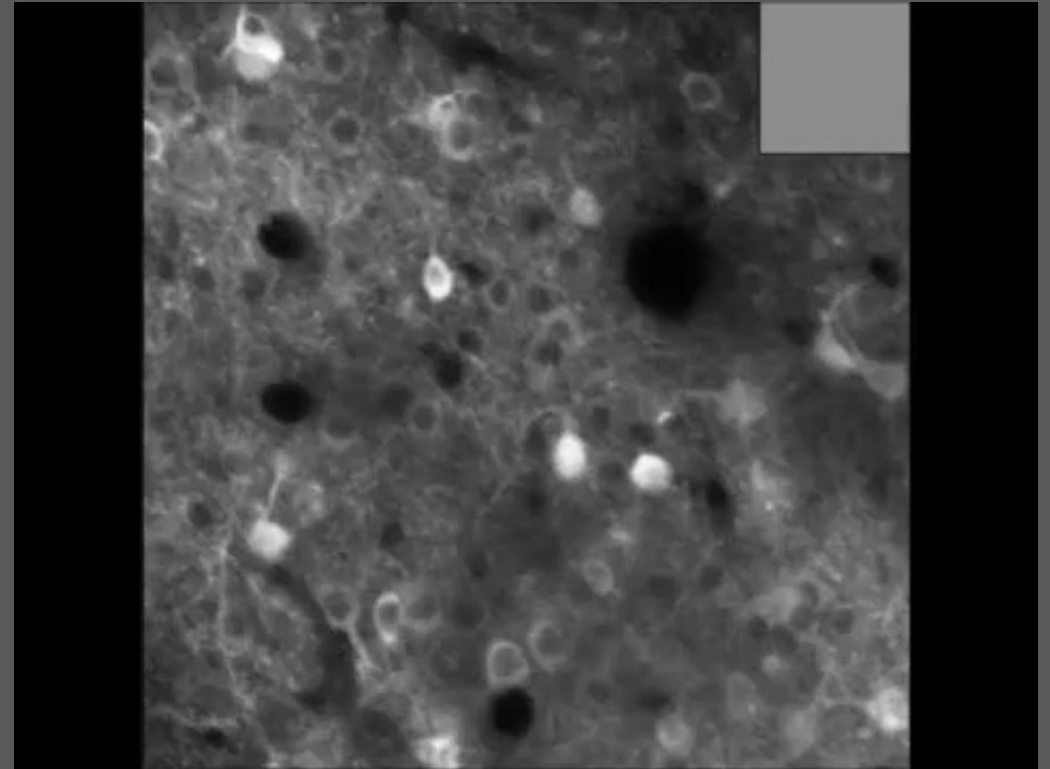
Disruptive Neuroscience 2: Listening to a concert of lots of neurons

Electrodes

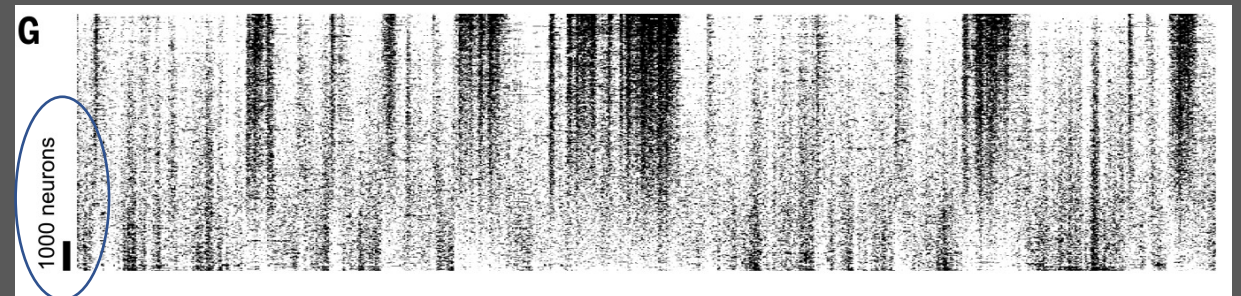


IMEC, Belgium

1. Recording from many neurons simultaneously
2. Following neurons over prolonged periods of time



Sur Lab at MIT



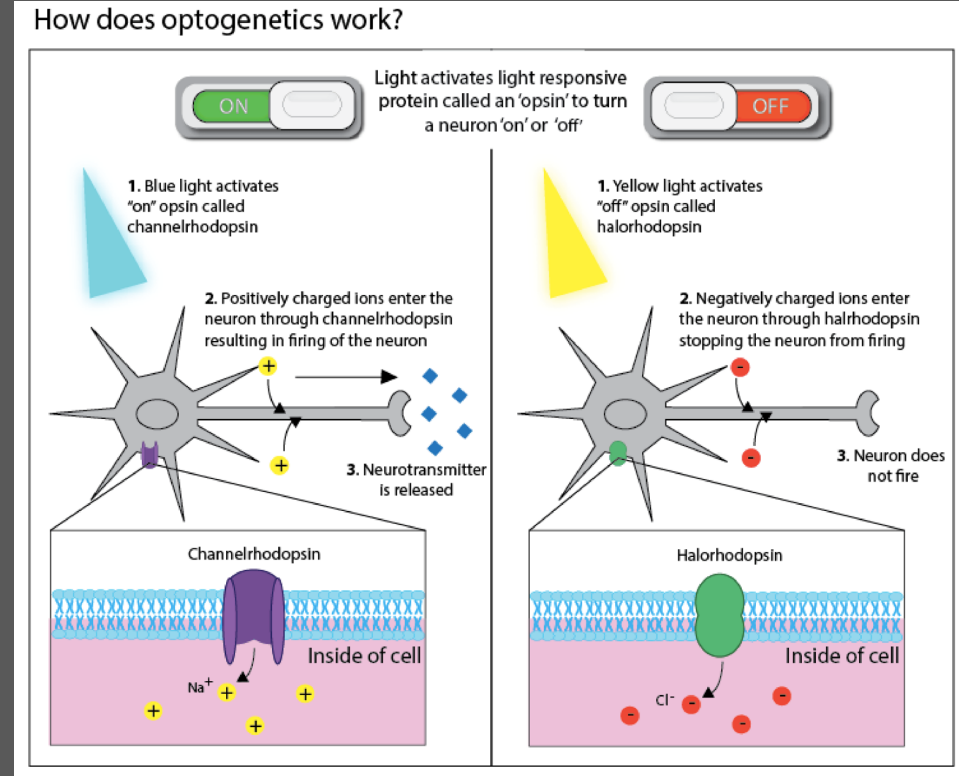
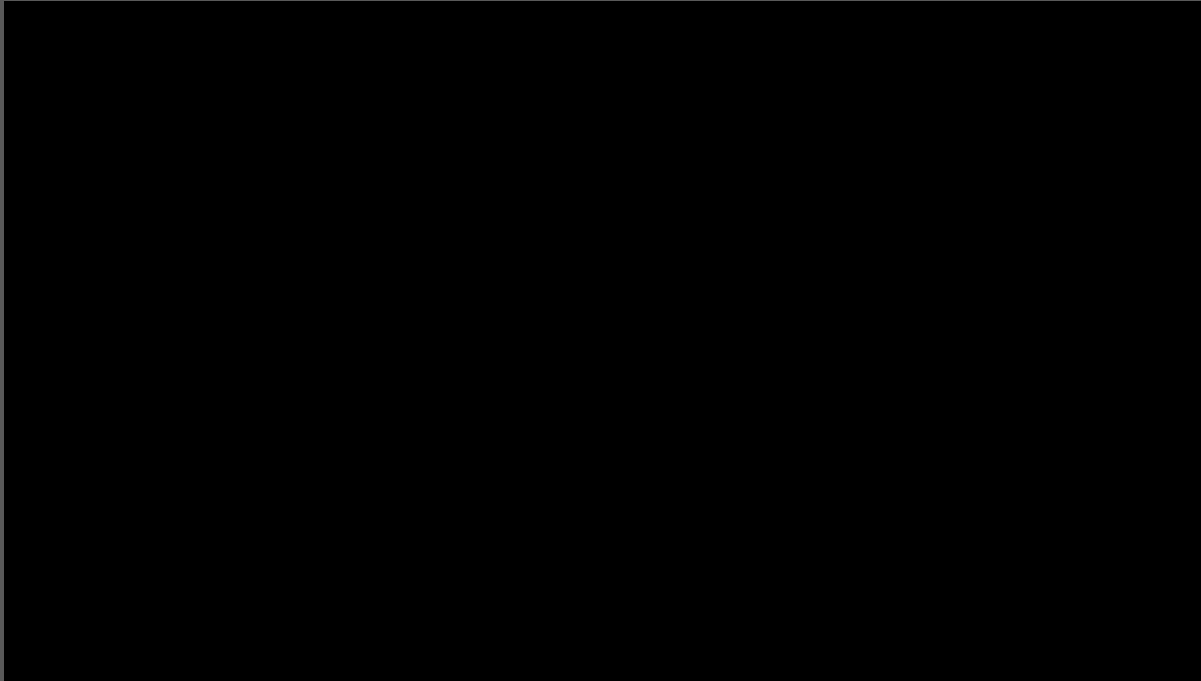
Fully integrated silicon probes for high-density recording of neural activity. Jun, Steinmetz, ..., Harris. Nature 2017

Stringer et al Science 2019

Disruptive new technologies in Neuroscience

1. Circuit level diagrams
2. Recording the activity of many neurons
3. Causally interfering with neural activity

Disruptive Neuroscience 3: Causally interfering with neural activity



Ed Boyden



Millisecond-timescale, genetically targeted optical control of neural activity.
Boyden, Zhang, Bamberg, Nagel, Deisseroth, Nature Neuroscience 2005

Consciousness

SPECIAL ARTICLE

CONSCIOUSNESS AND NEUROSURGERY

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Received, January 9, 2004.
Accepted, April 8, 2004.

THE NEURONAL BASIS of consciousness is the greatest challenge to the scientific world-view. Much relevant empirical work is carried out on the minimal neuronal mechanisms underlying any one specific conscious percept. Two broad approaches are popular among brain scientists: electrophysiological recordings from individual neurons in the cortex of behaving monkeys or behavior combined with functional brain imaging in humans. However, many aspects of consciousness are problematic or remain off-limits to the former approach, while the latter one lacks sufficient spatial and temporal resolution to monitor individual neurons that are key to perception, thought, memory, and action. It is here that neurosurgeons, probing the living human brain on a daily basis, can play a decisive role. This article explores the contributions of neurosurgeons to this quest and outlines some of the results that have already been achieved.

KEY WORDS: Cerebral cortex, Consciousness, Electrical stimulation, Medial temporal lobe, Neuronal correlates of consciousness, Single-neuron recordings, Visual awareness

Neurosurgery 55:273-282, 2004 DOI: 10.1227/01.NEU.0000129279.26534.76 www.neurosurgery-online.com

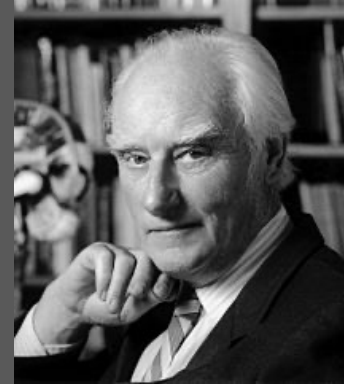
In a rough way, we all know what it is like to be conscious. The neurosurgeon uses the terms "conscious" and "unconscious" in daily practice. The presence of consciousness and, more importantly, the absence or impairment of consciousness have immediate implications for the neurological assessment of the patient. The clinician realizes that between the extreme states of consciousness and coma stand a variety of intermediate states, or altered states of consciousness. Like the Eskimo's vocabulary for snow, neurologists and neurosurgeons have developed a detailed vocabulary and numerical scales for *impaired* or *altered* consciousness. The clinician uses such terms as *clouding of consciousness* (reduced wakefulness and awareness), *delirium*, *obtusation*, and *stupor* (40) as well as a numerical scale for *coma*, the Glasgow Coma Scale. These terms do little to further scientific understanding of consciousness. They are arguably useful in communicating a patient's neurological status, but appearances may be misleading. The patient in a persistent vegetative state may seem conscious but has no real interaction with the environment, whereas the "locked-in" patient may seem unconscious but only lacks effective means of communicating his conscious self to the observer. The Glasgow Coma Scale uses motor responsiveness, speech, and eye opening as measures to assess

consciousness. But none of these faculties is necessary or sufficient for consciousness.

Despite the more pressing need to treat the patient with impaired consciousness, neurosurgeons through the ages have realized that their work on the human brain poses a specific challenge. Some have taken this challenge beyond the immediate clinical question to ask how the brain gives rise to consciousness. Wilder Penfield addressed this question by observing his epilepsy patients during periods of behavioral automatism and by applying electrical stimulation to sites in the brain during neurosurgical procedures under local anesthesia (38, 39). His observations on alteration in the content of consciousness have captured the imagination of generations of neuroscientists. In a lecture delivered in 1936 and published in the Harvey Lectures, Penfield addressed the neurosurgical community in the following words:

The neurosurgeon has a unique opportunity for psychological study when he exposes the brain of a conscious patient, and no doubt it is his duty to give account of such observations upon the brain to those more familiar with the mind. He may find it difficult to speak the language of psychology, but it is hoped that material of value to psychologists may be presented, the application

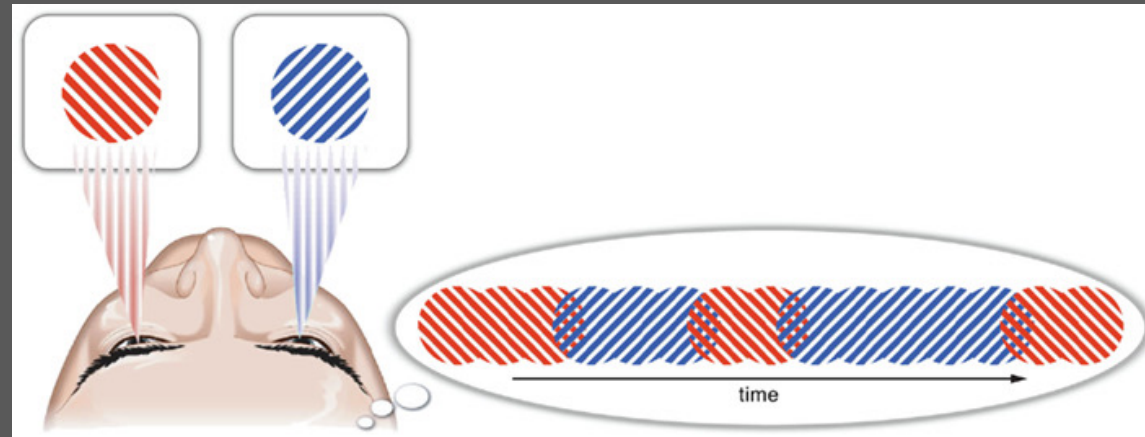
Francis Crick



Christof Koch



Binocular rivalry



Ascribing feelings to machines



The Tamagotchi effect



Do you take this robot ...
NY Times 19Jan2019



Is it evil to push Atlas?

Perils of AI

1. Redistribution of jobs (akin to but perhaps larger than the Industrial Revolution)
2. Unlikely: Terminator-like scenarios
3. Military applications
4. To err is algorithmic (human too)
5. Biases in training data (note that humans have biases too)
6. Lack of “understanding” (note that we do not necessarily understand how humans make decisions either)
7. Social, mental, and political consequences of rapid changes in labor force
8. Rapid growth, faster than development of regulations

