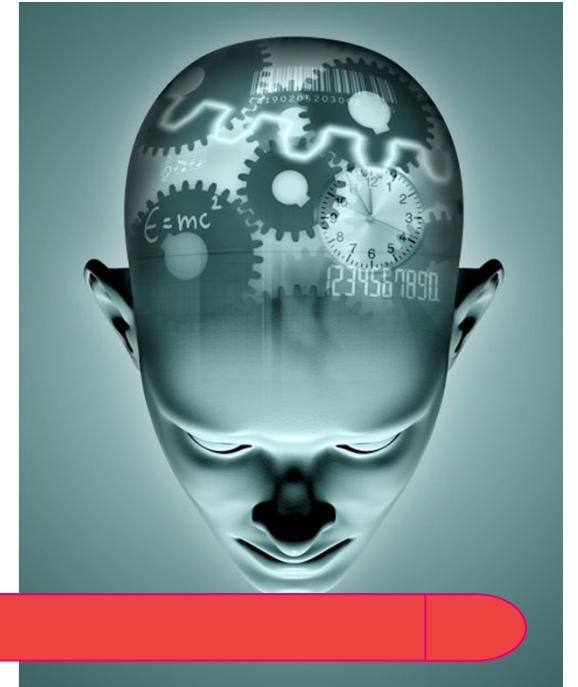


# Neuroeconomics :

## Neuroscience of decision making

Lecture N1



## Introduction

**Vasily Klucharev**

- Higher School of Economics

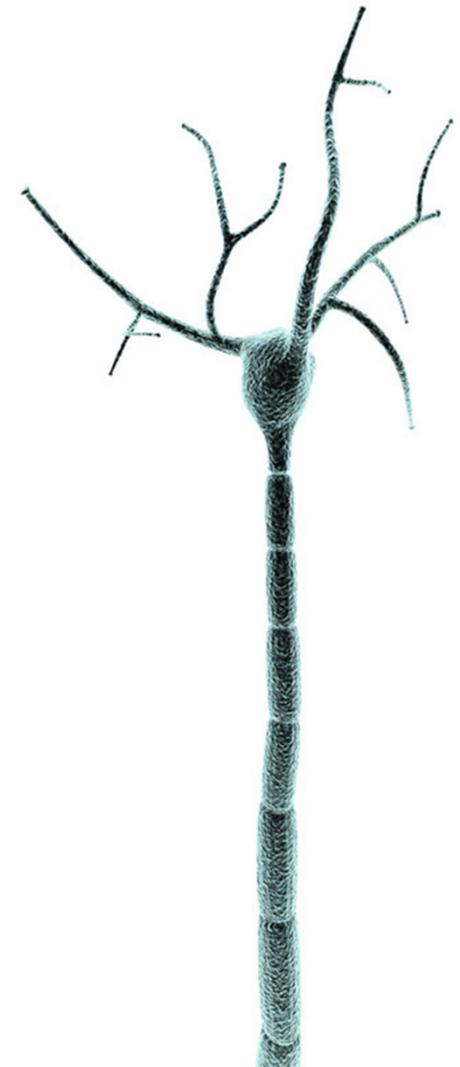
## **Course Structure:**

**Module I: “How the Brain works”**

**Module II: “How the Brain decides”**

**Module III: “How the Brain feels”**

**Module IV: “Society of Brains”**



# **What to expect/ don't expect from the course:**

## **Expect**

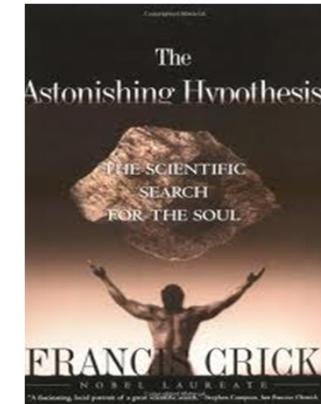
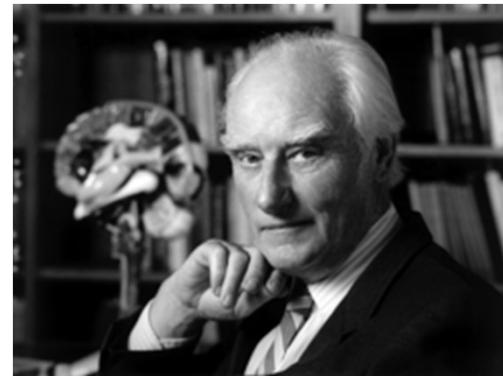
- Short introduction to Neuroeconomics
- Limitations of Neuroeconomics
- Trivial and nontrivial facts
- Discussion of multidisciplinary paradigms
- Difficult papers to read

## **Do not expect**

- A unified theory
- Discussion of all aspects of Neuroeconomics
- Easy to read handbooks

# The Astonishing Hypothesis:

- “ A person's mental activities are entirely due to the behavior of nerve cells, glial cells, and the atoms, ions, and molecules that make them up and influence them. ”

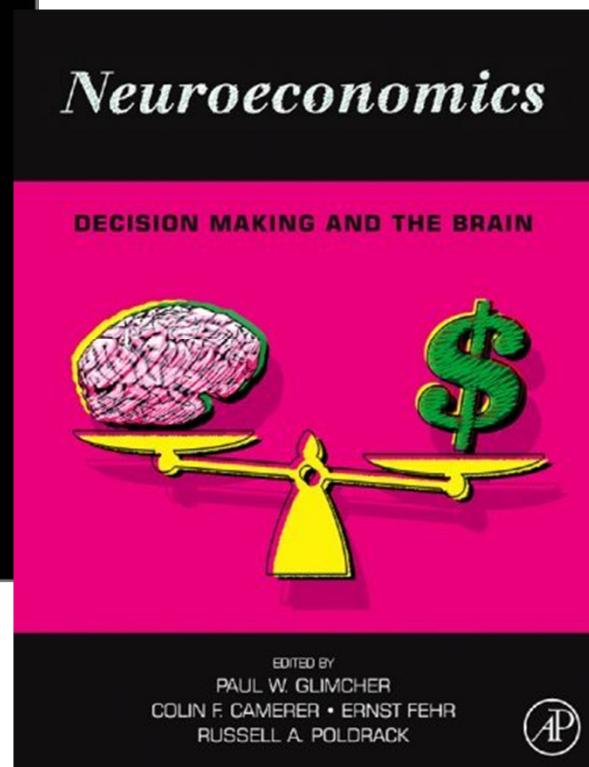
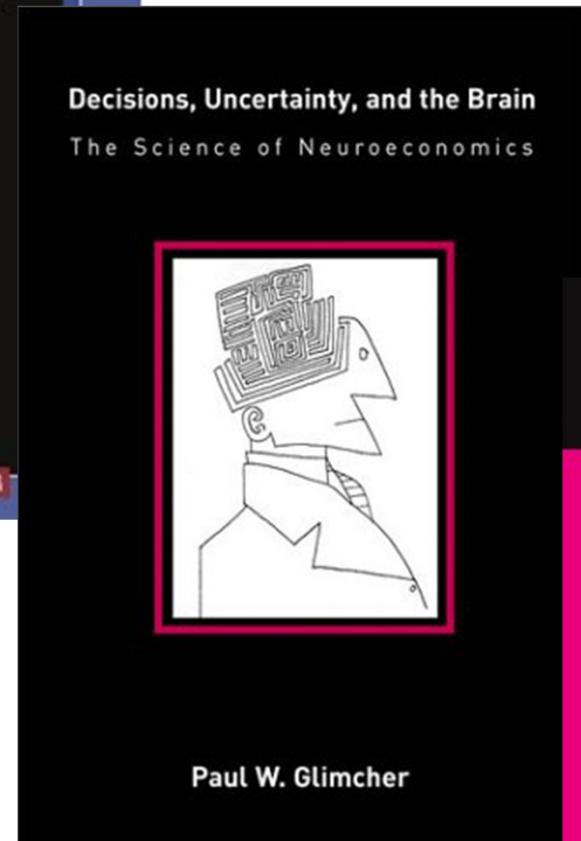
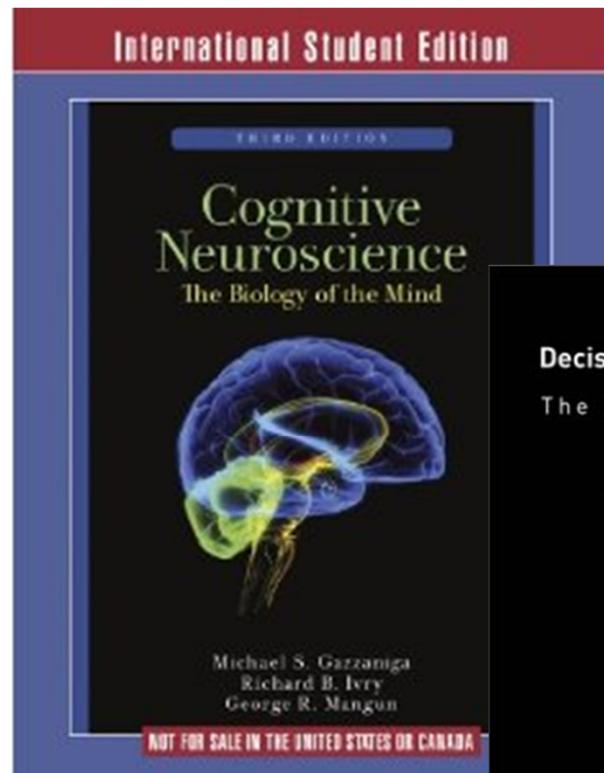


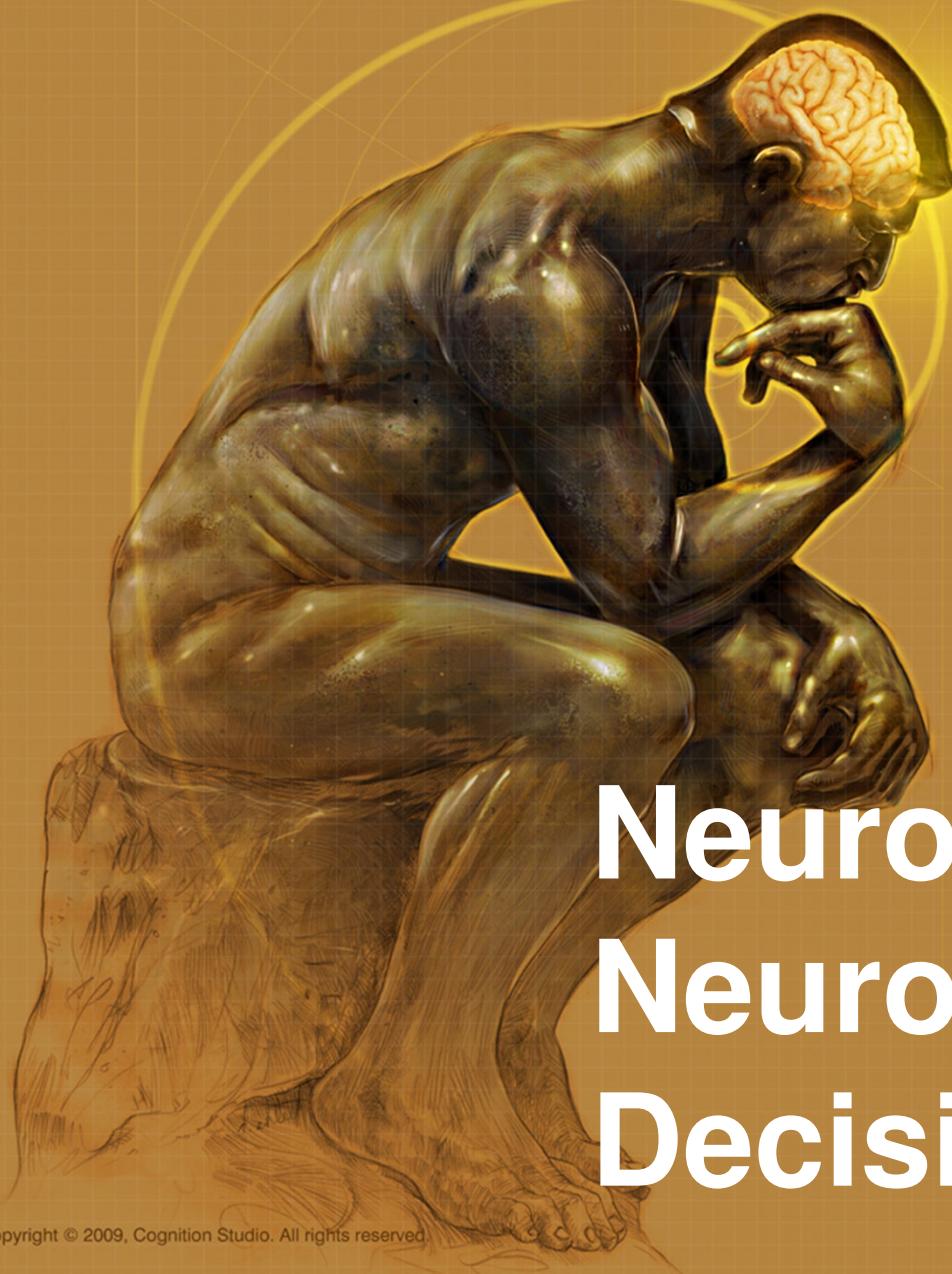
**Francis Crick (1916 –2004)**

# Neuroeconomics perspective:

- Economics, psychology, and neuroscience are converging today into a single, unified discipline with the ultimate aim of providing a single, general theory of human behavior - **neuroeconomics**.
- The goal of this discipline is to understand the processes that connect sensation and action by revealing the neurobiological mechanisms by which decisions are made.

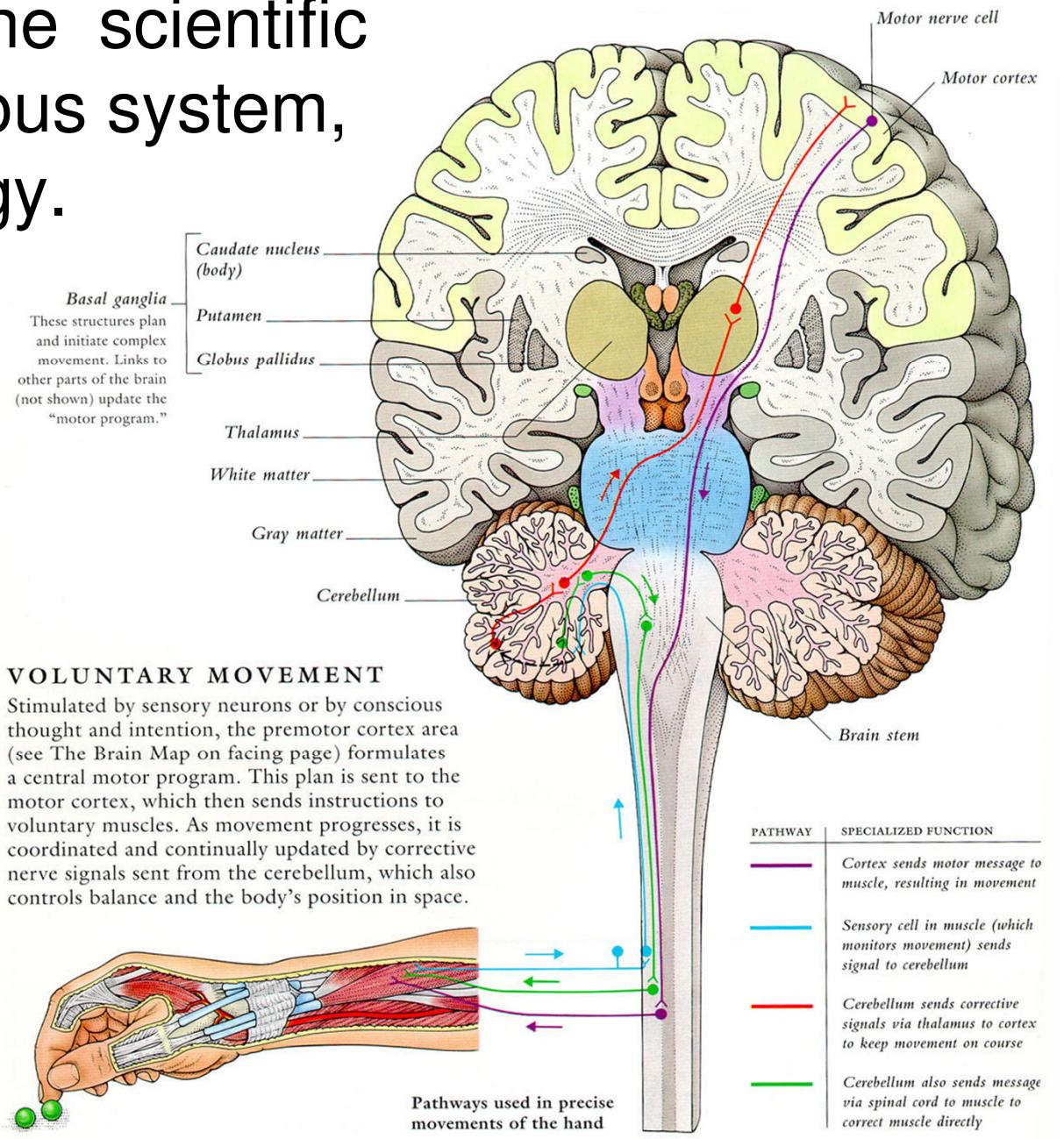
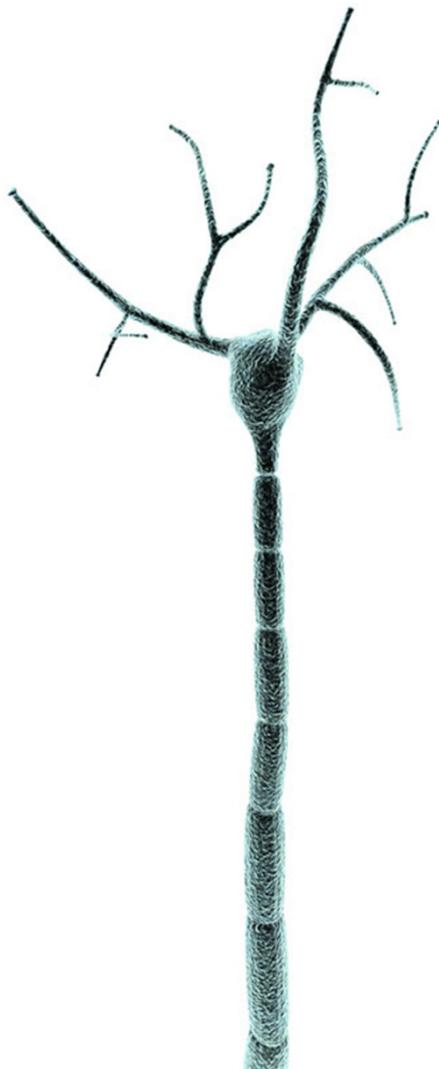
Adopted from Glimcher&Rustichini, Science 2004



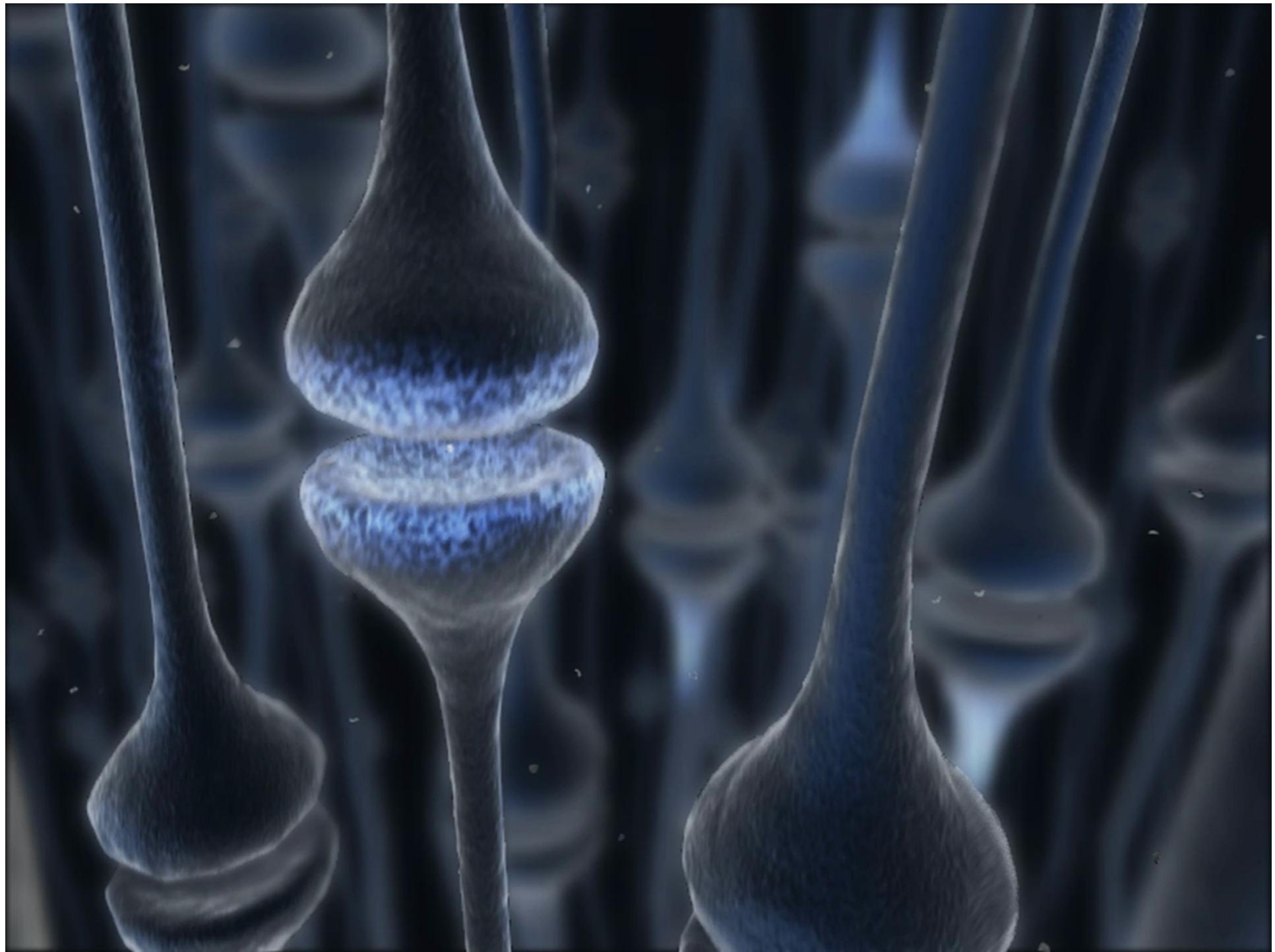


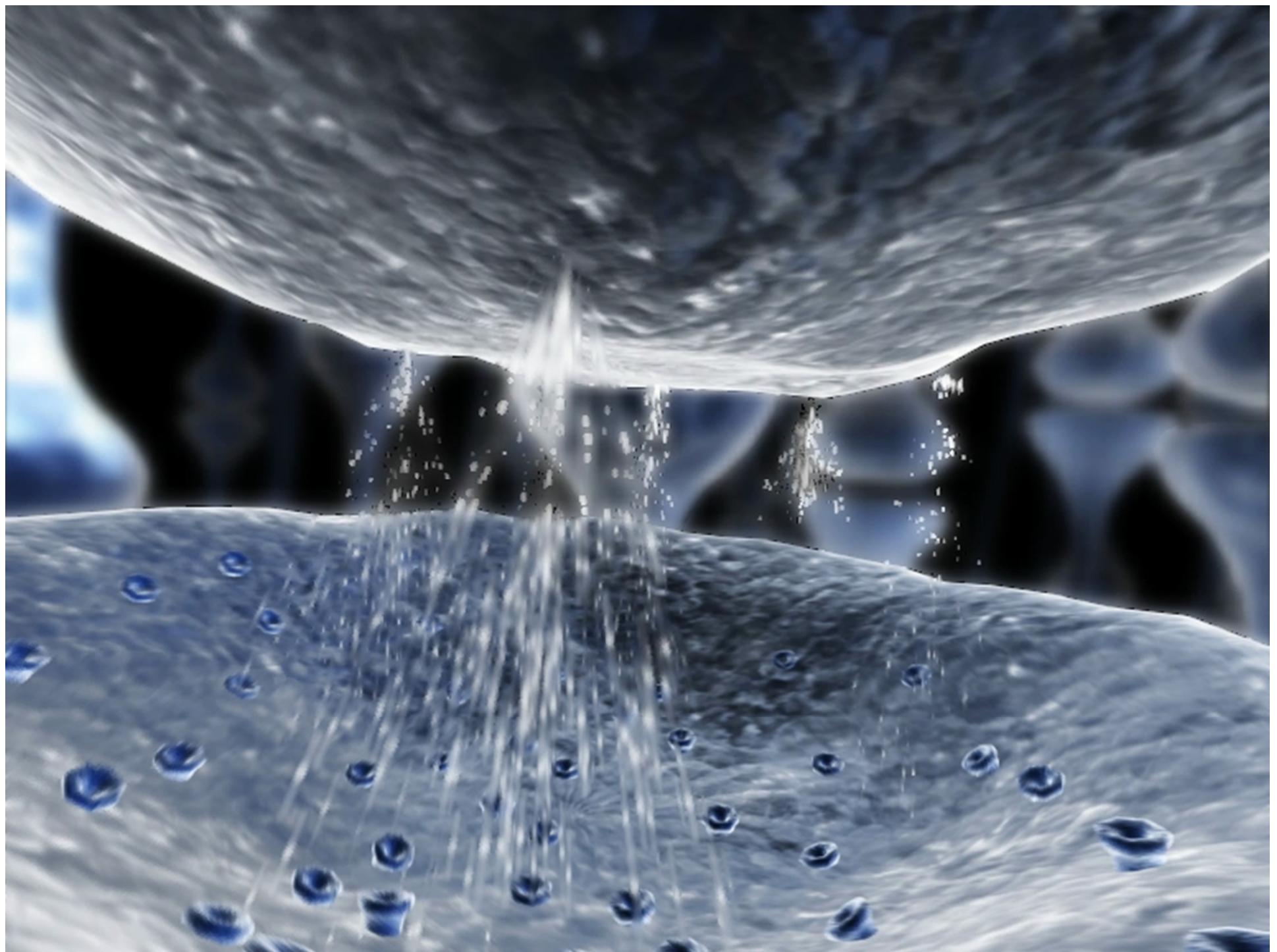
# Neuroeconomics = Neuroscience of Decision making

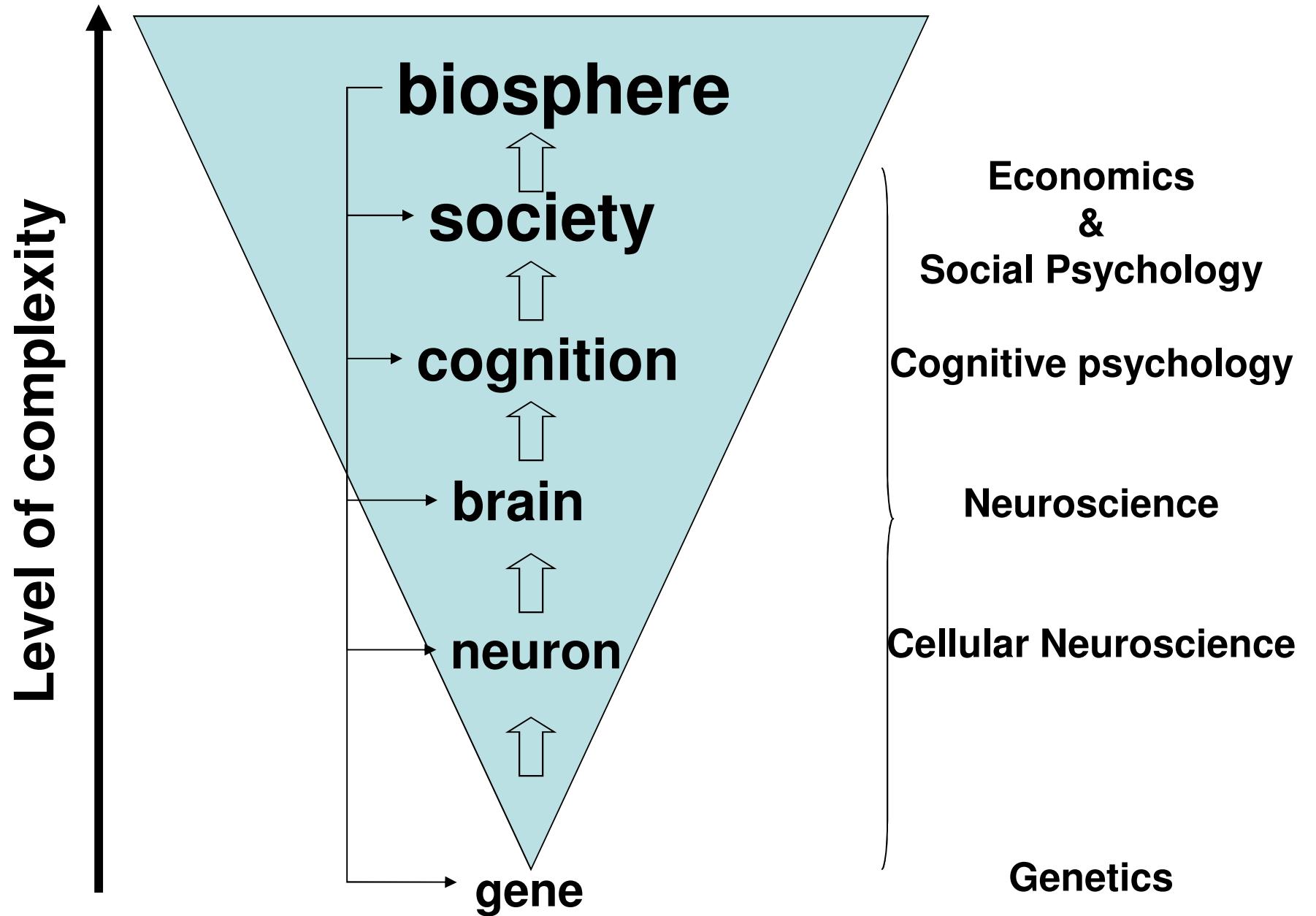
- Neuroscience – the scientific study of the nervous system, a branch of biology.

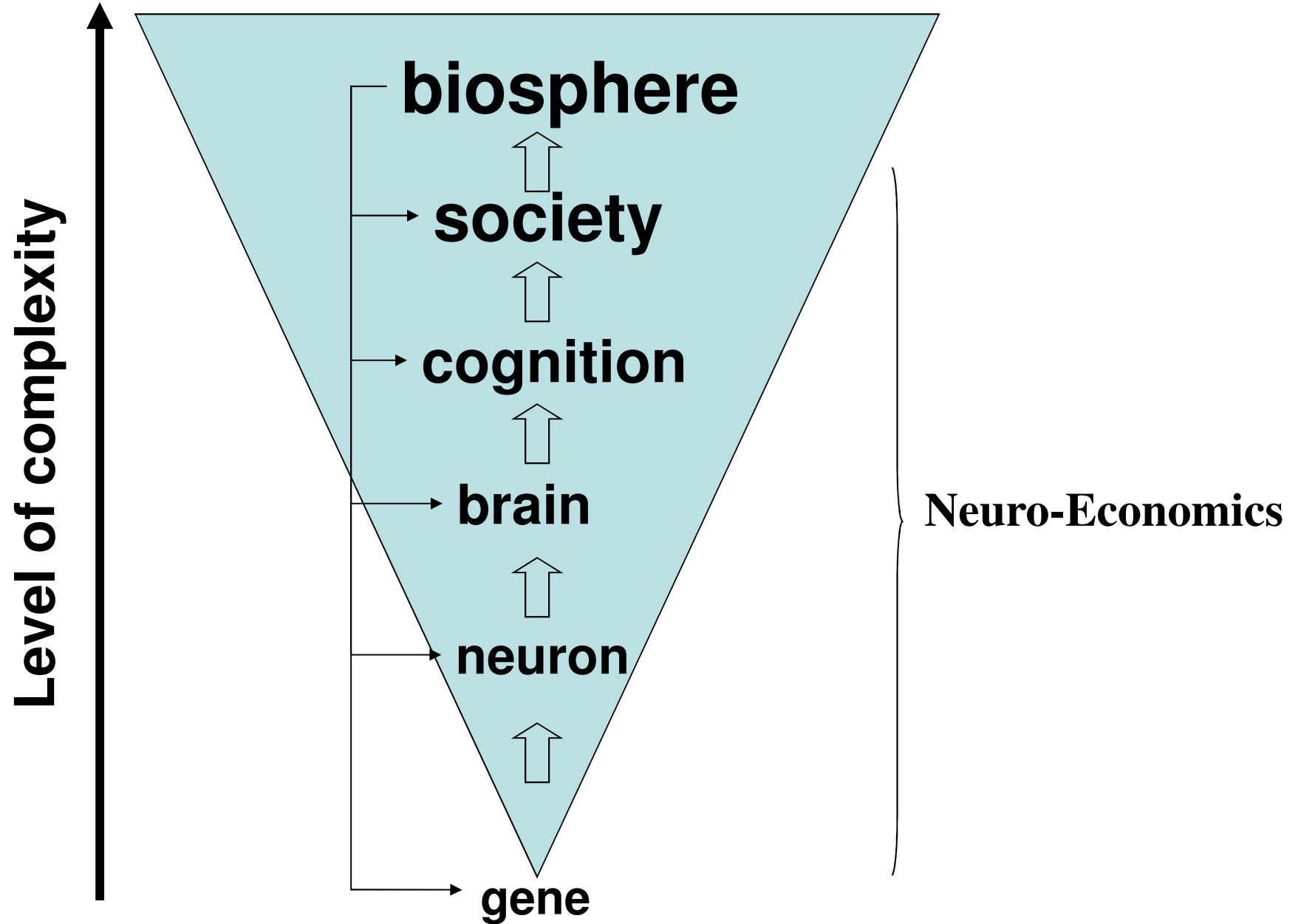


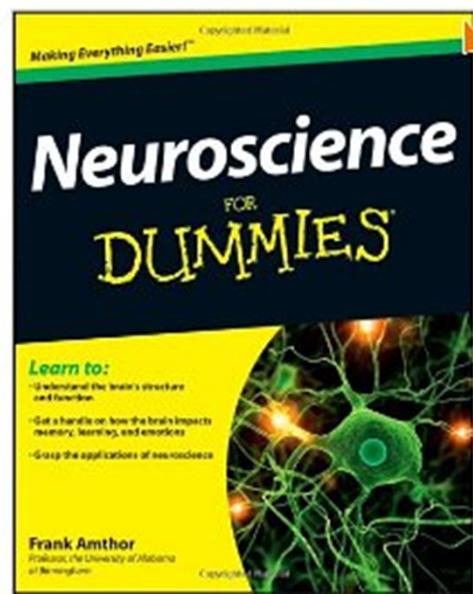
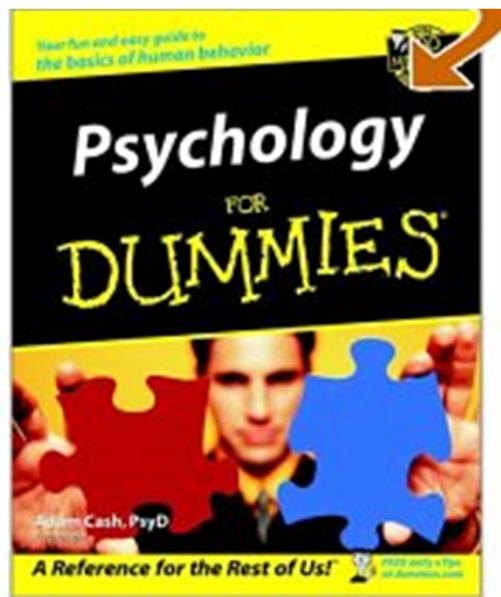
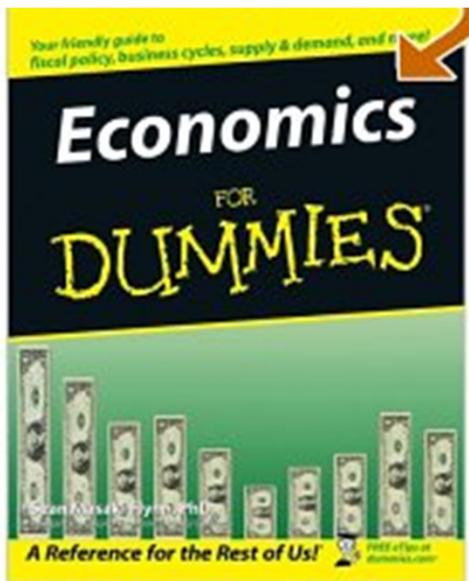












economics

social and cognitive  
psychology

neuroscience

some assumptions

rationality

???

## **Problem 1—The Asian Disease**

Imagine that the United States is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed.

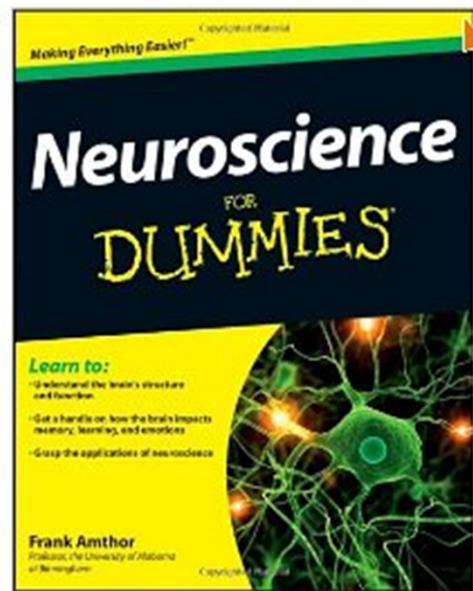
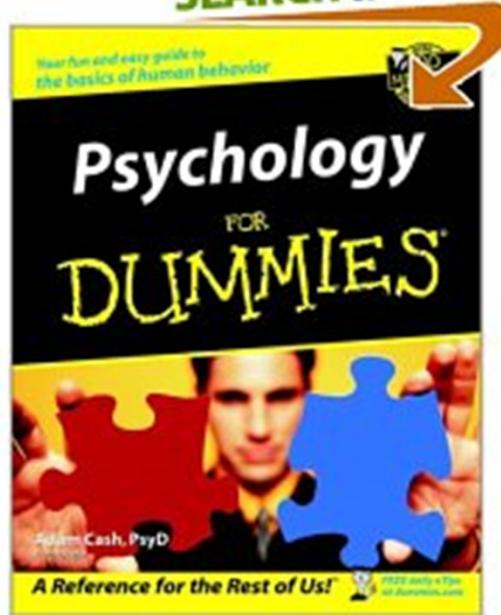
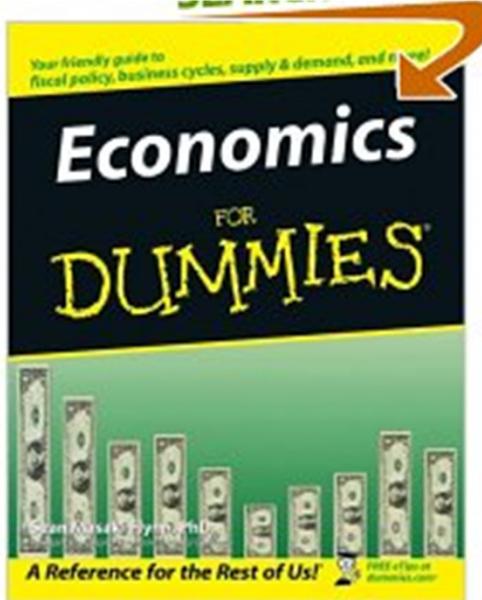
If Program A is adopted, 200 people will be saved.

If Program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved.

Which one of the two programs would you favor?

If Program A' is adopted, 400 people will die.

If Program B' is adopted, there is a one-third probability that nobody will die and a two-thirds probability that 600 people will die.



economics

social and cognitive  
psychology

neuroscience

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???

cognitive structures  
are real

???

# *Circular reasoning* problem

- In current psychological models the existence of *cognitive systems* is postulated from observation and analysis of behavior, which in turn is used to explain behavior.
- The only way to solve this dilemma was to use tools or methods that enable researchers to investigate behavior in a new, more objective way - perhaps *neuro-scientific*.



Brain Research Bulletin 67 (2005) 343–354

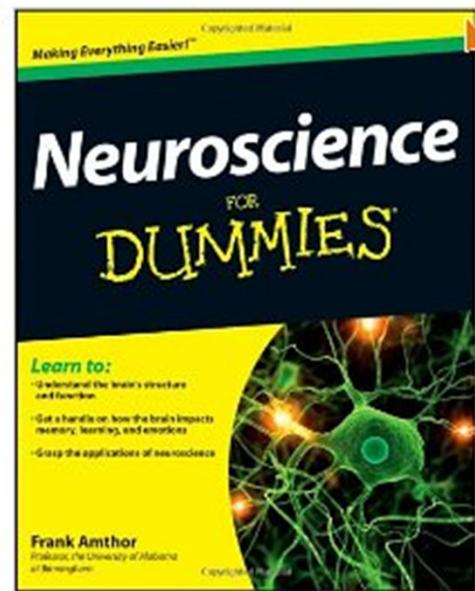
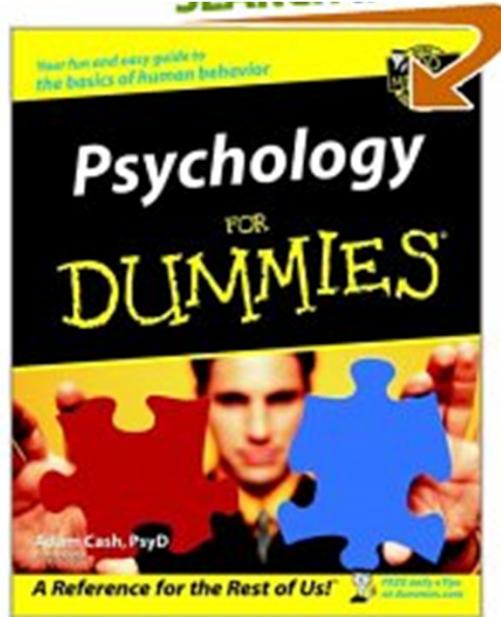
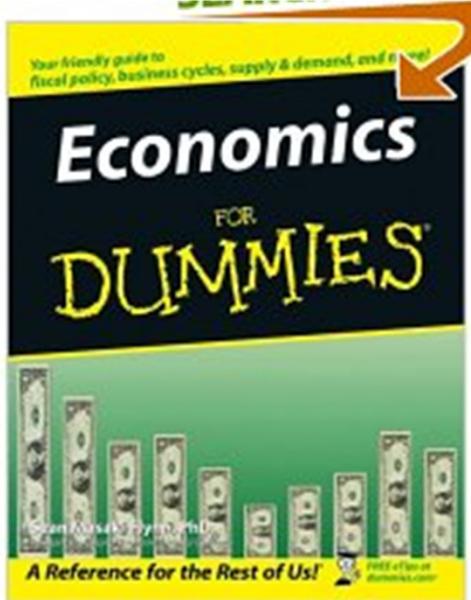


NeuroEconomics: An overview from an economic perspective

P. Kenning\*, H. Plassmann

Department of General Management, University of Münster, Münster, Germany

Available online 11 August 2005



economics

social and cognitive  
psychology

neuroscience

some assumptions

Rationality

???

???

Cognitive structures  
are real

???

Actor's behavior is  
determined solely by  
actor's neurons

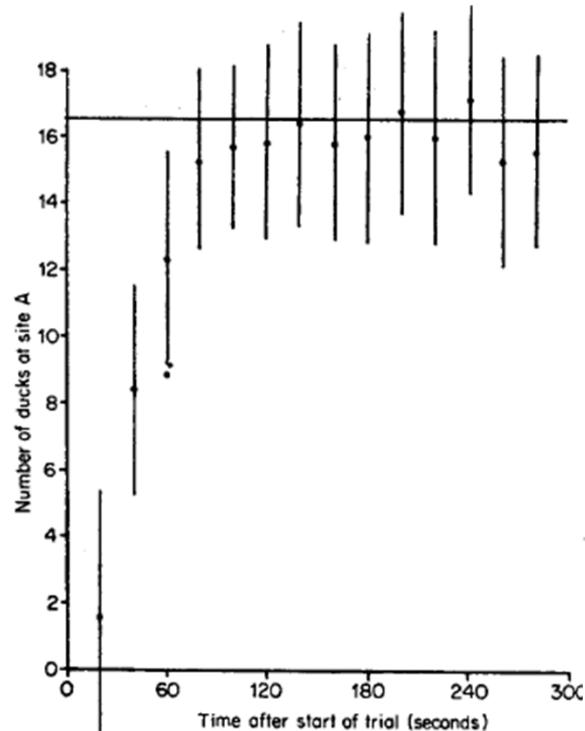


Fig. 1. Mean number of ducks at site A plotted against time since start of trial, when patch profitability ratio  $w_i$  unity. The horizontal line is the ideal free prediction.

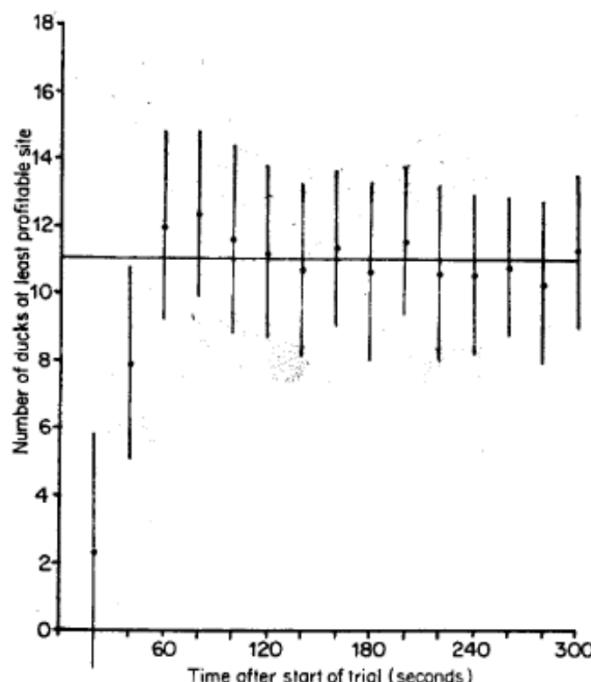
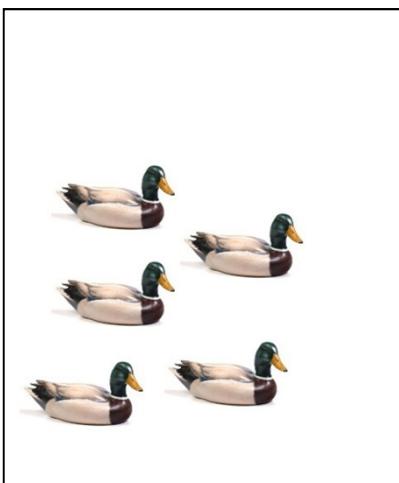


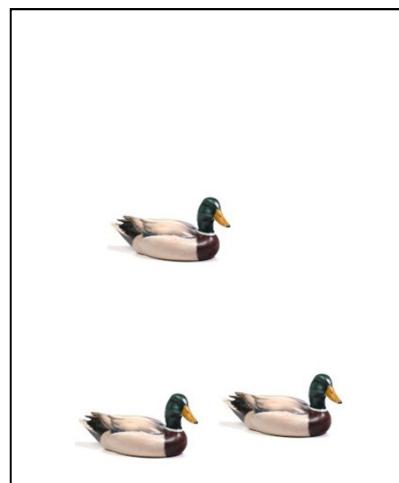
Fig. 2. Mean number of ducks at least profitable site plotted against time since start of trial, when patch profitability ratio was 2:1. The horizontal line is the ideal free prediction.



### A 2 gram per 5 sec



### B 2 gram per 10 sec



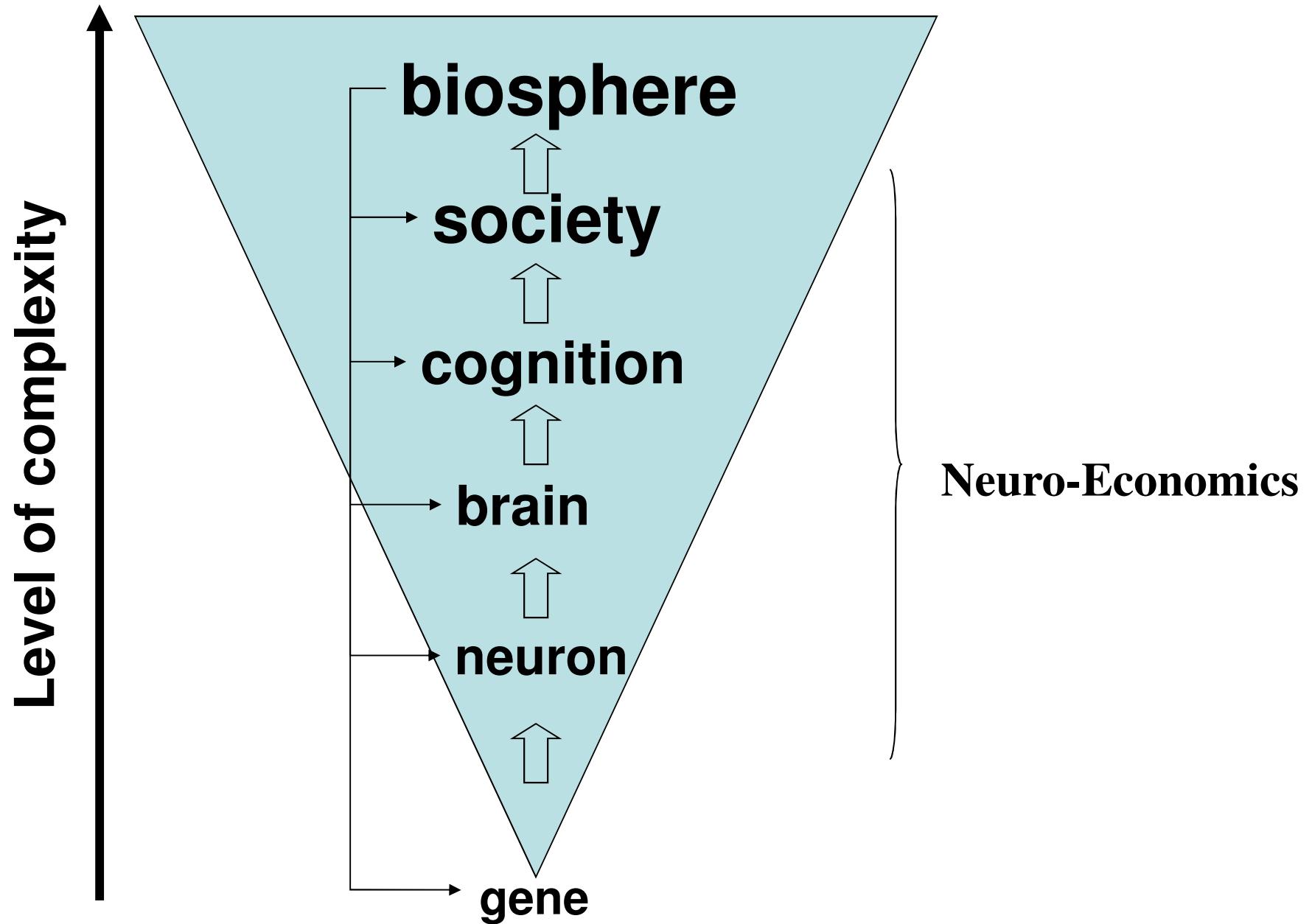
HARPER DGC

[COMPETITIVE FORAGING IN MALLARDS - IDEAL FREE DUCKS](#)

ANIMAL BEHAVIOUR 30 (MAY): 575-584 1982

Times Cited: [148](#)

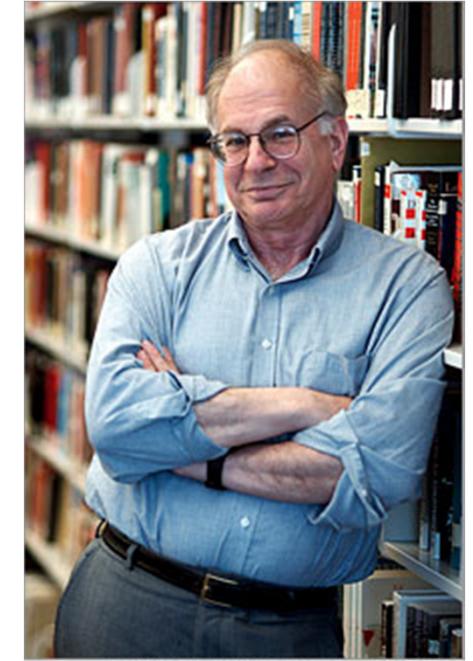




- Economics - social science studying the production, distribution, and consumption of wealth.
  - **Macroeconomics** studies a nation or the world's economy as a whole (e.g. inflation, and industrial production) to understand the past and predict the future.
  - **Microeconomics** studies the behavior of specific sectors of the economy, such as companies, industries, or households.

# Behavioral economics

## Daniel Kahneman



COURTESY: UNIVERSITY OF LOUISVILLE



# Experimental economics

## Vernon Smith

Nobel Prize in Economics in 2002



Paul Glimcher



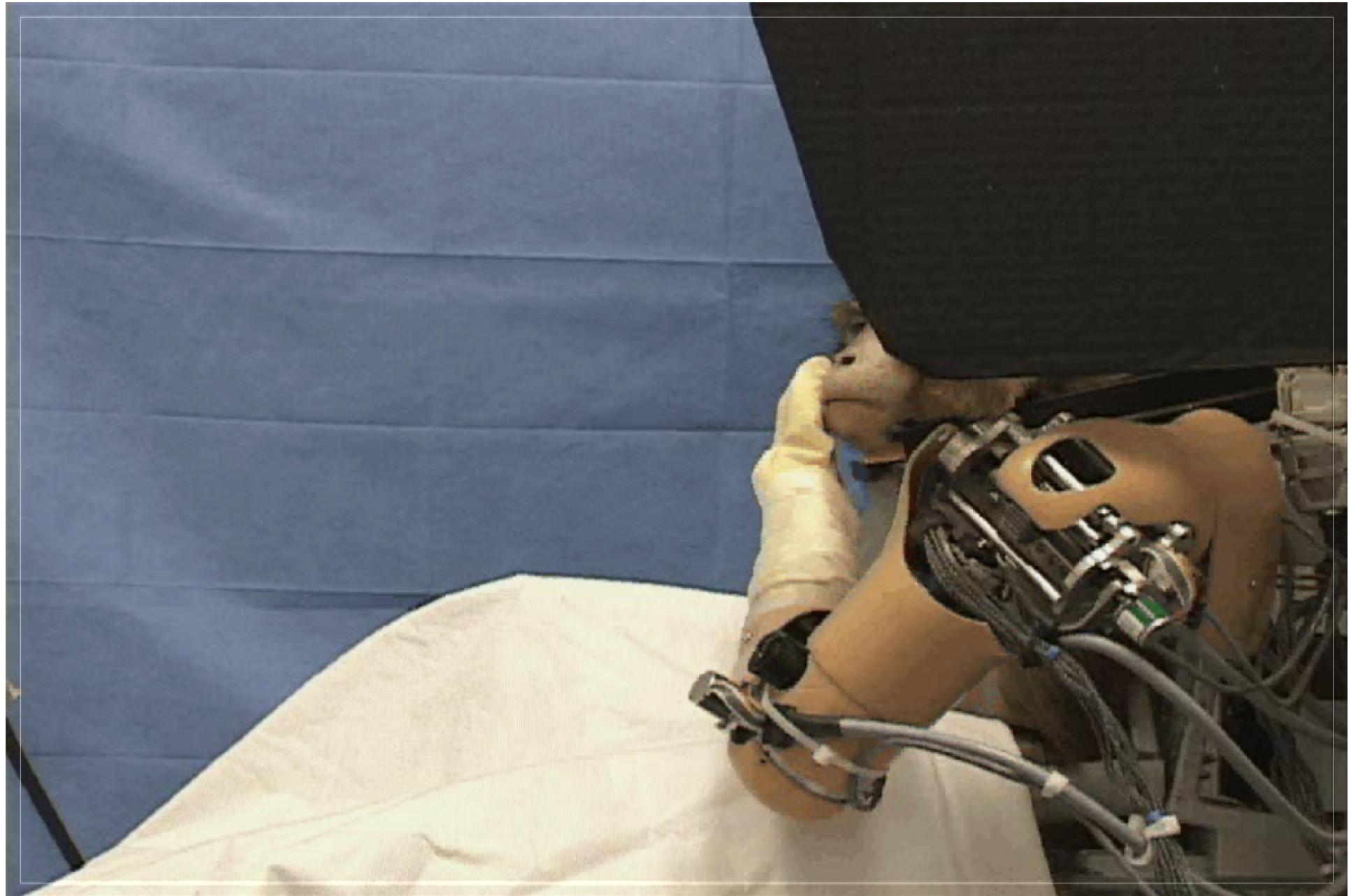
NEW YORK UNIVERSITY

<http://www.decisionsrus.com/>

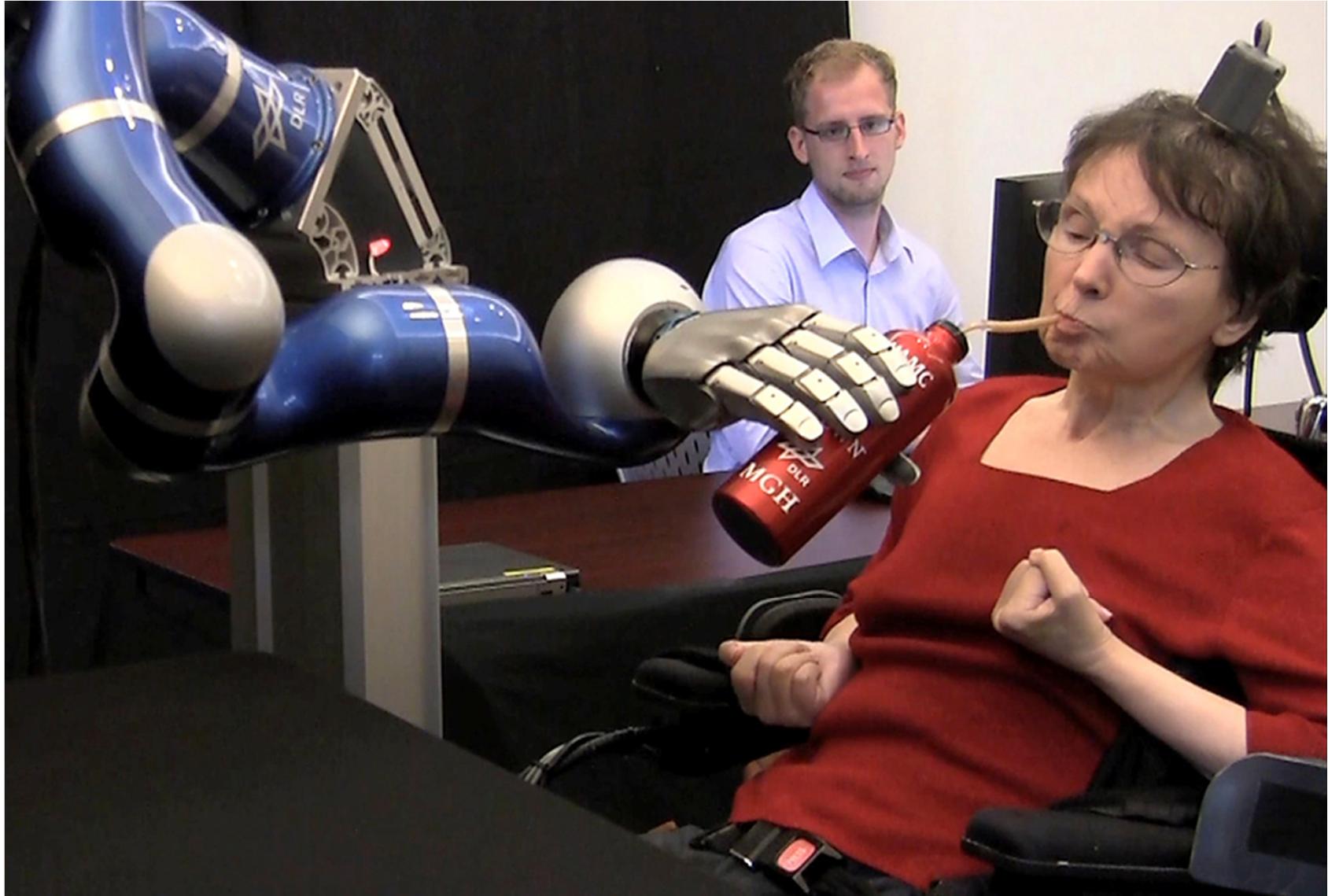
- **Core Neuroeconomics** or **Neuroscience of decision making** – a field of neuroscience that studies processes connecting sensation and action by revealing the neurobiological mechanisms by which decisions are made.
- **Extended Neuroeconomics** – a multidisciplinary field that studies mechanisms of decision making by integrating the evolutionary, neurobiological and social approaches.



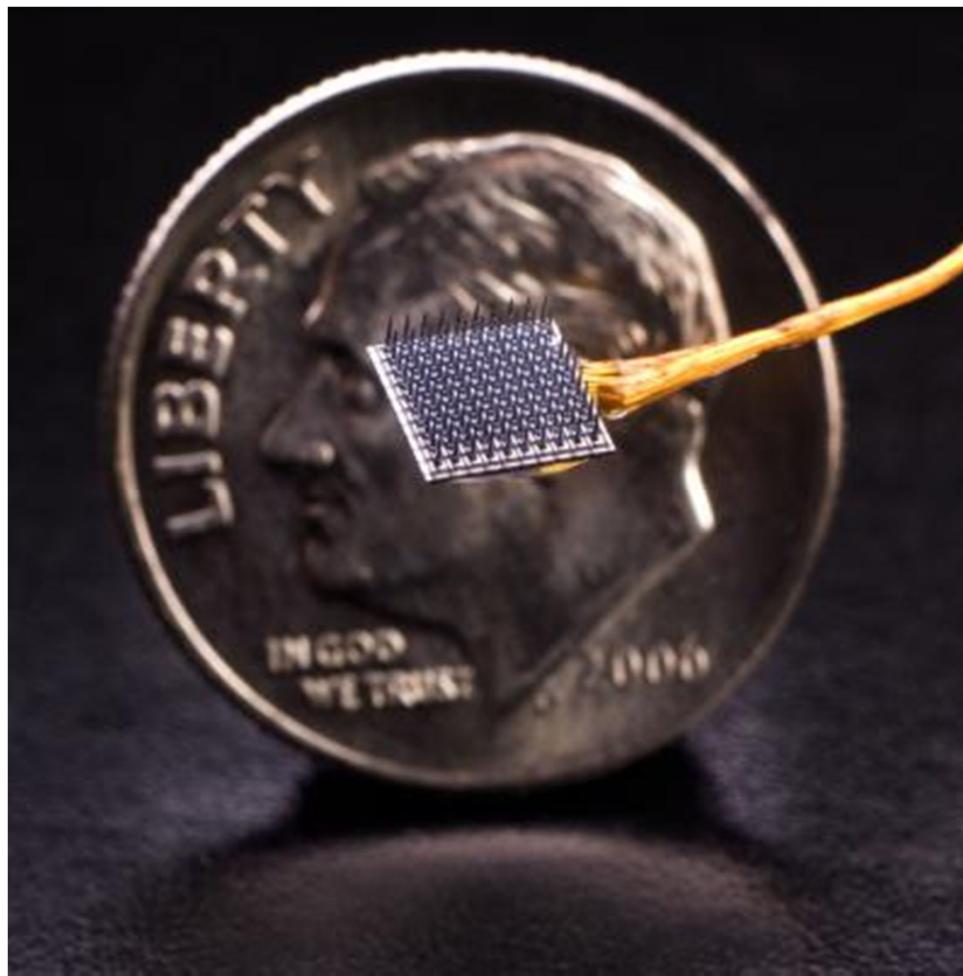
# Neuroeconomics



*Motorlab, University of Pittsburgh*



Brown University— On April 12, 2011, nearly 15 years after she became paralyzed and unable to speak, a woman controlled a robotic arm by thinking about moving her arm and hand to lift a bottle of coffee to her mouth and take a drink.



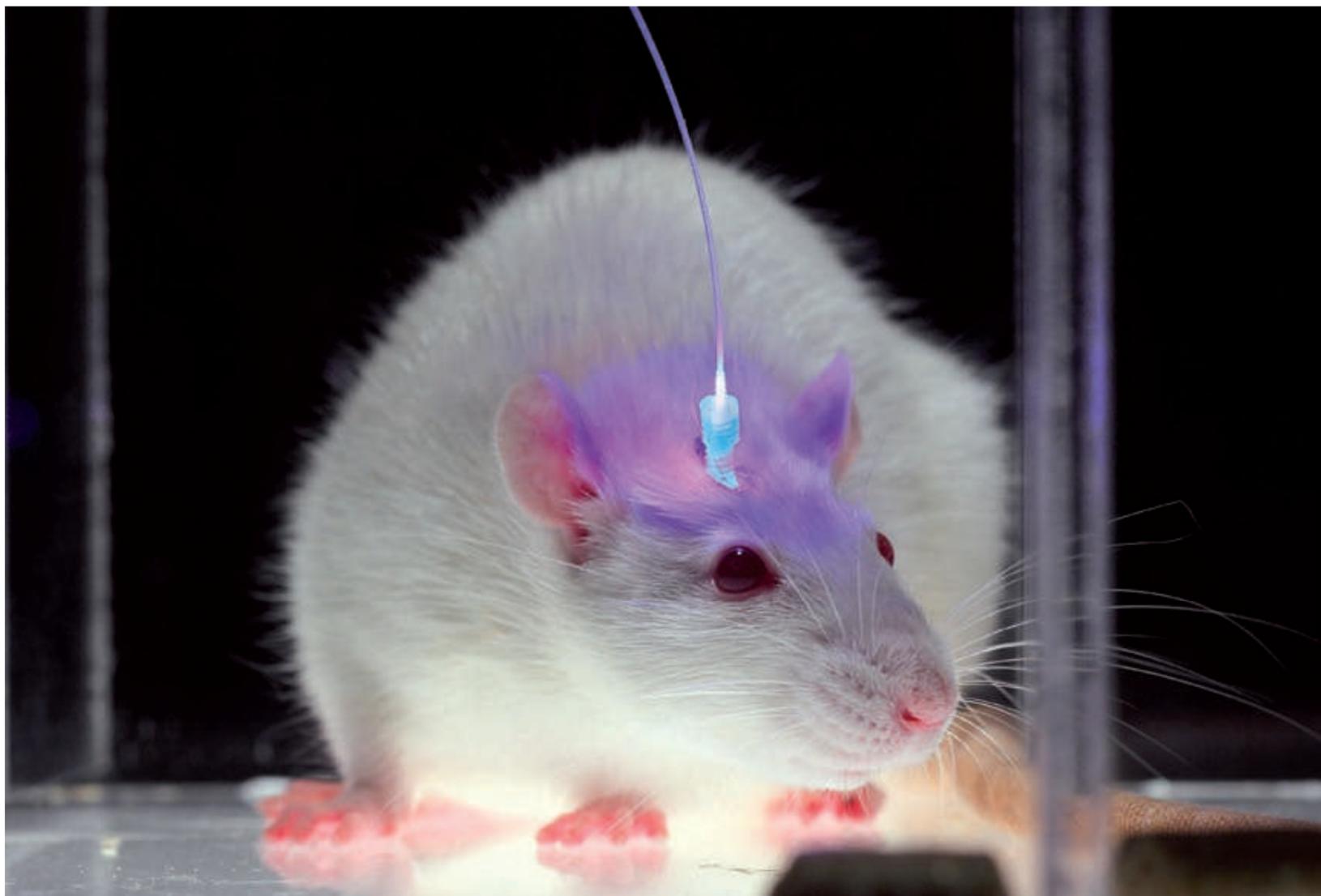
### **The BrainGate2 Neural Interface System**

An implanted microelectrode array, first used more than a decade ago, detects brain signals which can be translated by a computer into machine instructions, allowing control of robotic devices by thought.



The 52-year-old patient had been diagnosed with a degenerative brain and spinal disease 13 years earlier and eventually became unable to move her arms and legs. In February 2012, the researchers implanted two microelectrode arrays into the woman's left motor cortex

University of Pittsburgh



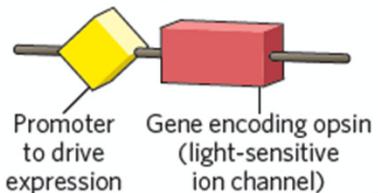
NATURE|Vol 465|6 May|2010

## SIX STEPS TO OPTOGENETICS

With optogenetic techniques, researchers can modulate the activity of targeted neurons using light.

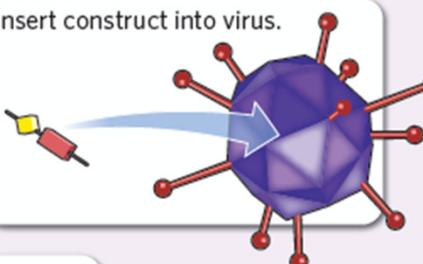
### STEP 1

Piece together genetic construct.



### STEP 2

Insert construct into virus.



### STEP 3

Inject virus into animal brain; opsin is expressed in targeted neurons.



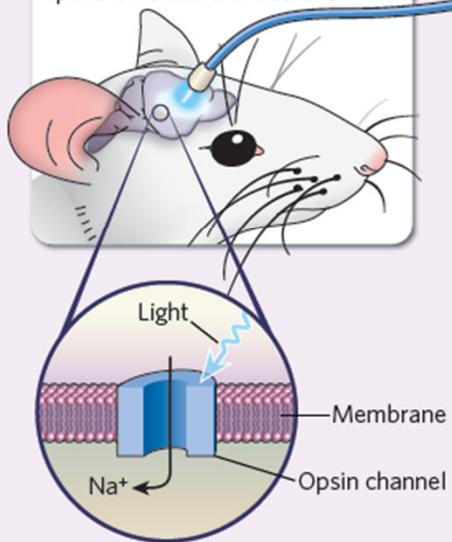
### STEP 4

Insert 'optrode', fibre-optic



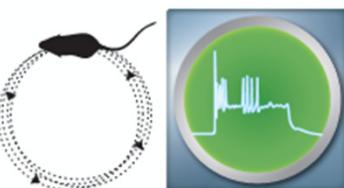
### STEP 5

Laser light of specific wavelength opens ion channel in neurons.



### STEP 6

Record electrophysiological and behavioural results.



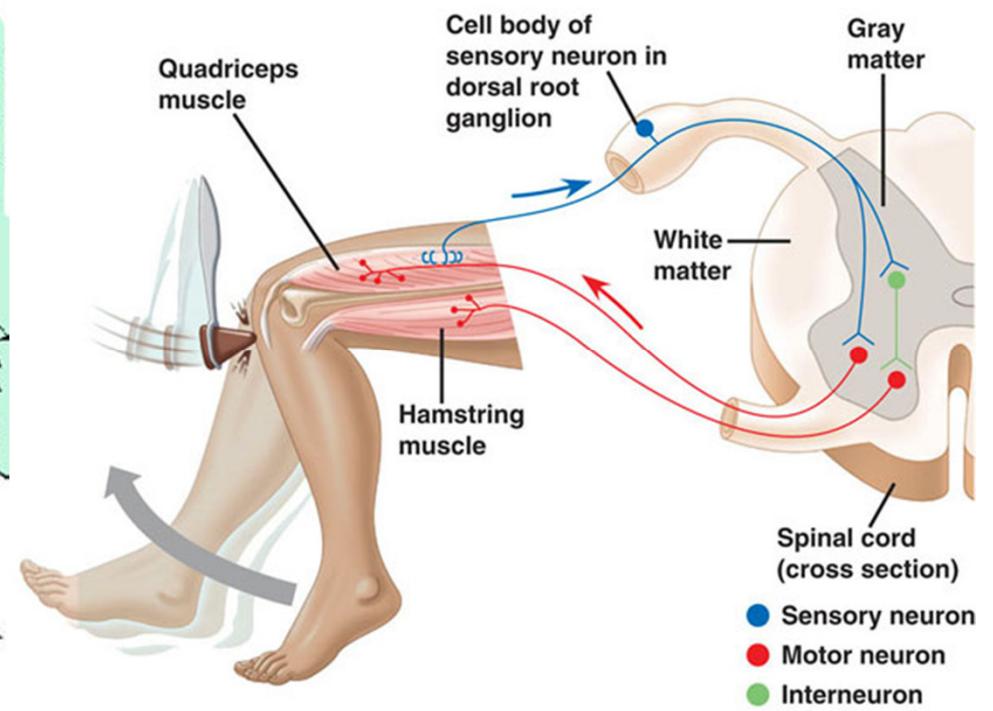
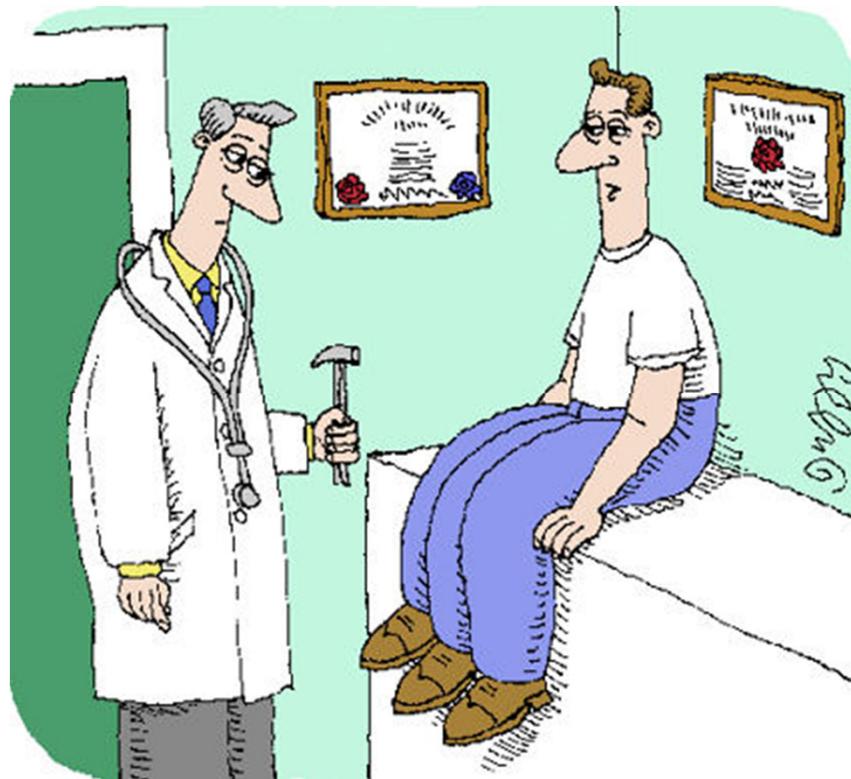
# **What is decision theory?**

Decision theory is a theory about decision making.

- **Do I see red or green color of the traffic lights?** – depends on our sensory system.
- **Shall I bring the umbrella tomorrow?** – depends on something which I do not know, namely whether it will rain or not.
- **Am I going to smoke the next cigarette?** – If I make the same decision sufficiently many times it may kill me.
- **A committee has to make a decision, but its members have different opinions.** – How to overcome disagreements?

Sven Ove Hansson

# Main assumptions:



1. There are options to choose between

## 2. We choose in a non-random way



vs



## 3. Our choices are goal-directed activities.



vs



# Main assumptions

- There are options to choose between
- We choose in a non-random way
- Our choices are goal-directed activities.

Overall, decision theory is concerned with goal-directed behavior in the presence of options.

# Normative and descriptive theories

- A **normative** decision theory – a theory about how decisions should be made
- A **descriptive** theory – a theory about how decisions are actually made.

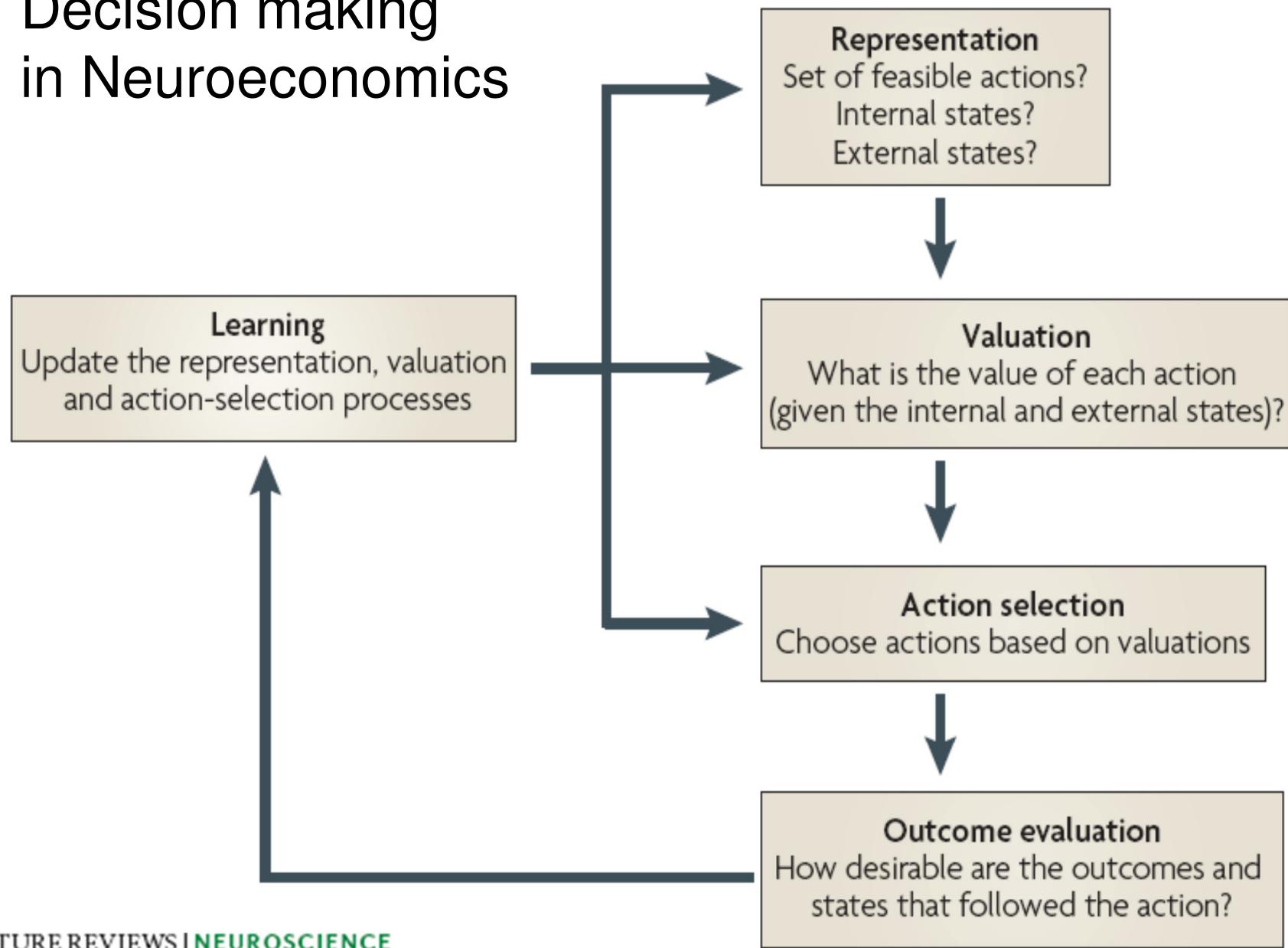


Condorcet	First discussion		Second discussion		Resolution
Simon	Intelligence	Design		Choice	
Mintzberg et al	Recognition	Diagnosis	Search/ Design	Screen	Evaluation - choice Authorization
Brim et al	Identification	Obtaining information	Production of solutions	Evaluation	Selection

*Diagram 2. A comparison of the stages of the decision process according to Condorcet, Simon, Mintzberg et al and Brim et al.*

Sven Ove Hansson

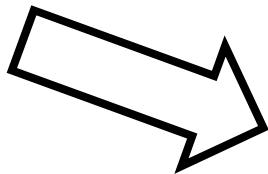
# Decision making in Neuroeconomics



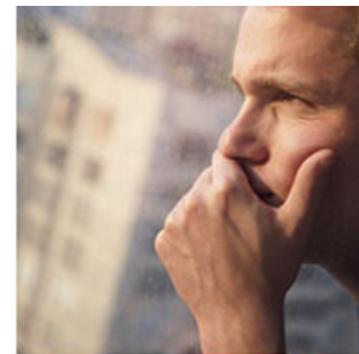
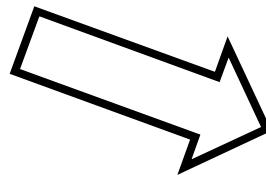
# Ultimatum Game



Sum = 100\$



Split = 95:5\$



Decision?

Two anonymous players

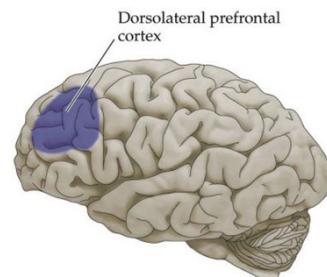
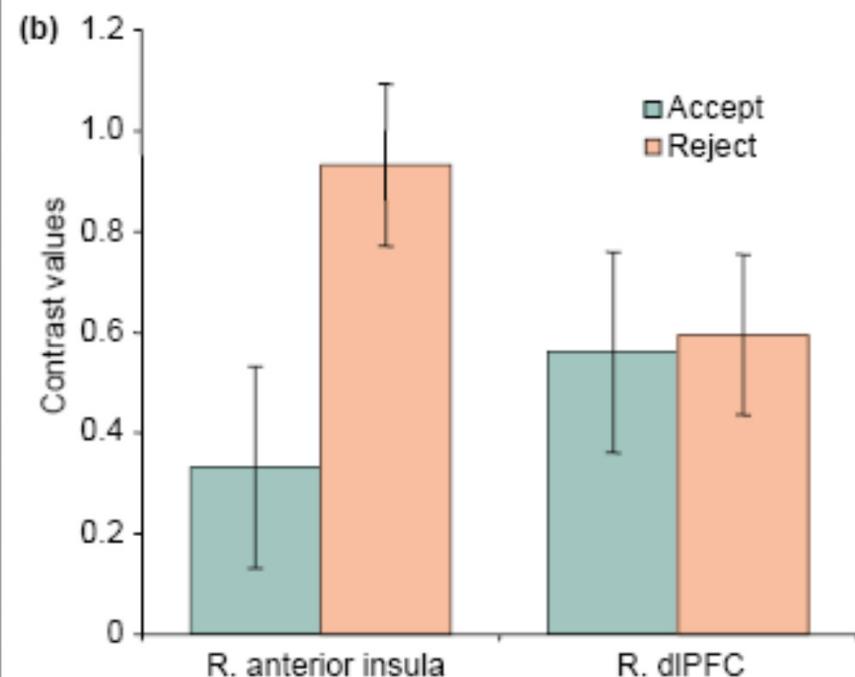
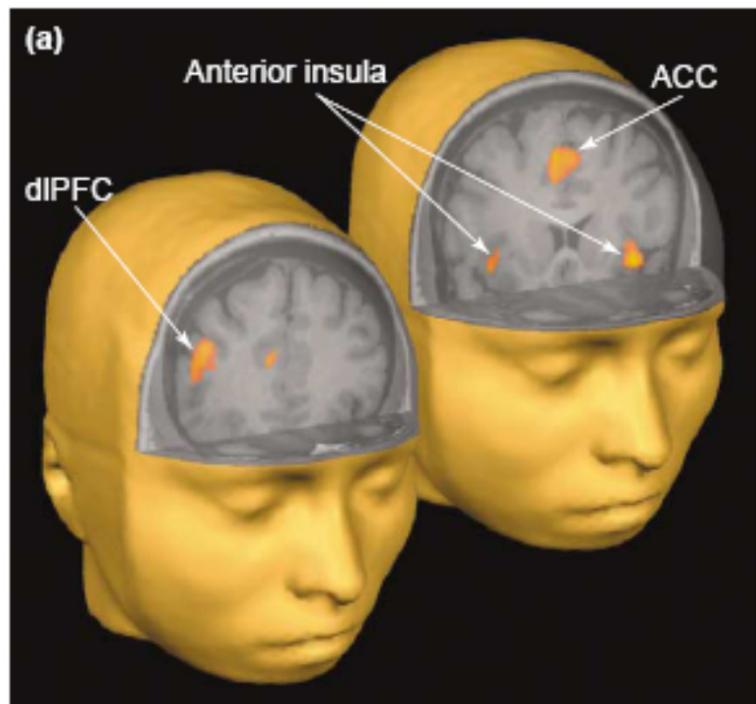
1<sup>st</sup> player divides a sum of money

2<sup>nd</sup> player can accept or reject this proposal.

- If he/she rejects, neither player receives anything
- If he/she accepts, the money is split according to the proposal

Game is played only once, and anonymously - reciprocation is not an issue.

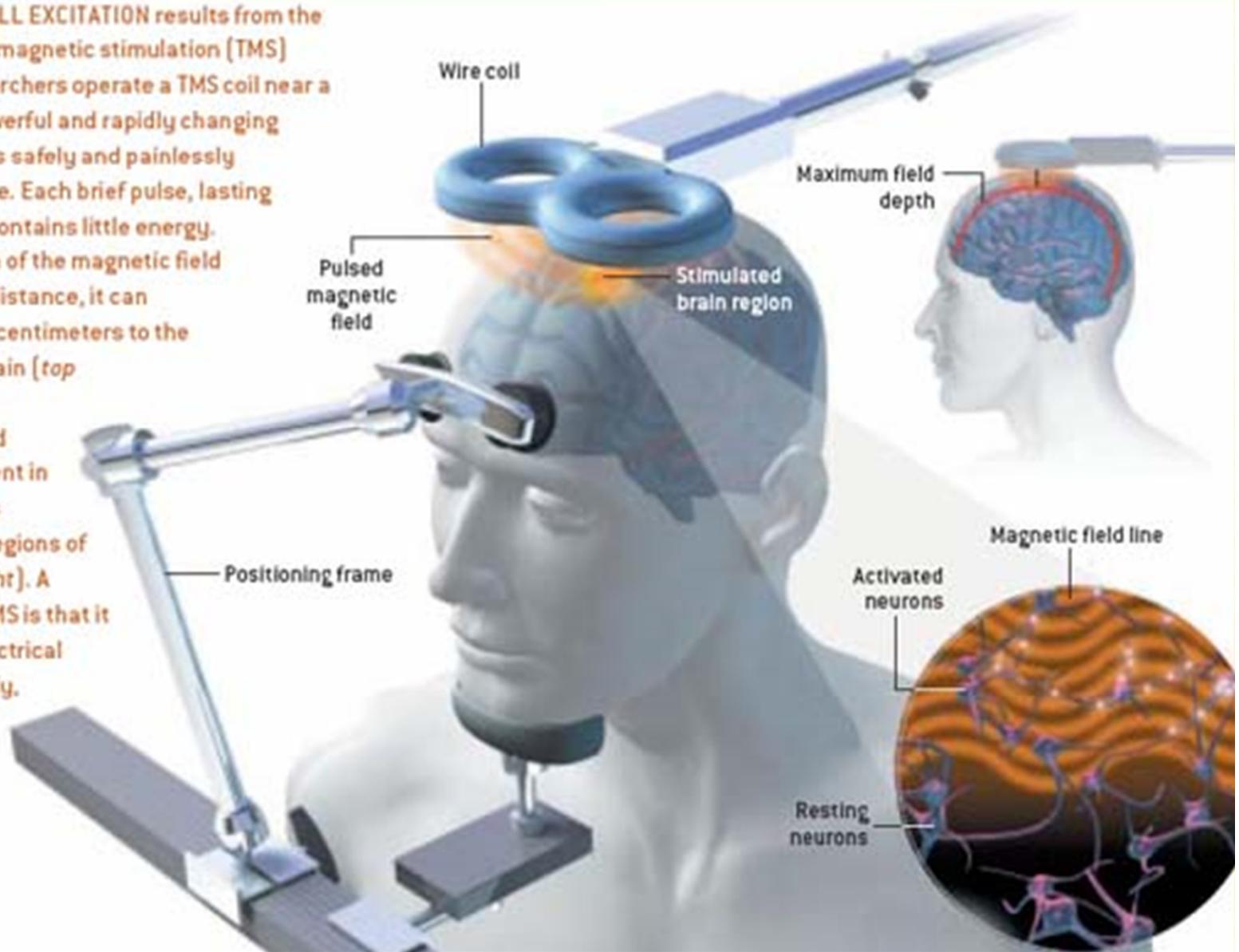
An unfair offer in the Ultimatum Game leads to conflict between emotional, ‘reject’, and cognitive, ‘accept’, systems.



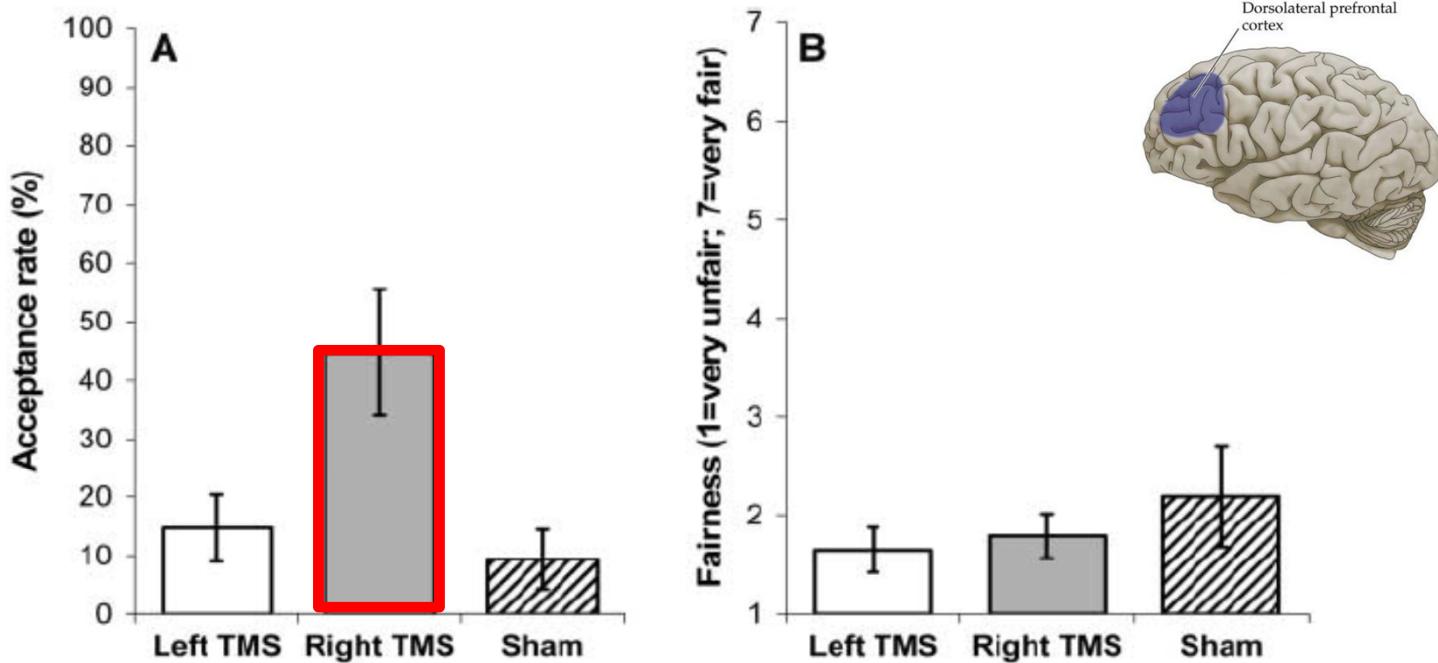
Sanfey et al 2003

## TRANSCRANIAL MAGNETIC STIMULATION

LOCALIZED BRAIN-CELL EXCITATION results from the use of a transcranial magnetic stimulation (TMS) machine. When researchers operate a TMS coil near a subject's scalp, a powerful and rapidly changing magnetic field passes safely and painlessly through skin and bone. Each brief pulse, lasting only microseconds, contains little energy. Because the strength of the magnetic field falls off rapidly with distance, it can penetrate only a few centimeters to the outer cortex of the brain [top right]. On arrival, the precisely located field induces electric current in nearby neurons, thus activating targeted regions of the brain [bottom right]. A principle benefit of TMS is that it requires no direct electrical connection to the body, as is required for electroconvulsive therapy.



# DLPFC - dorsolateral prefrontal cortex

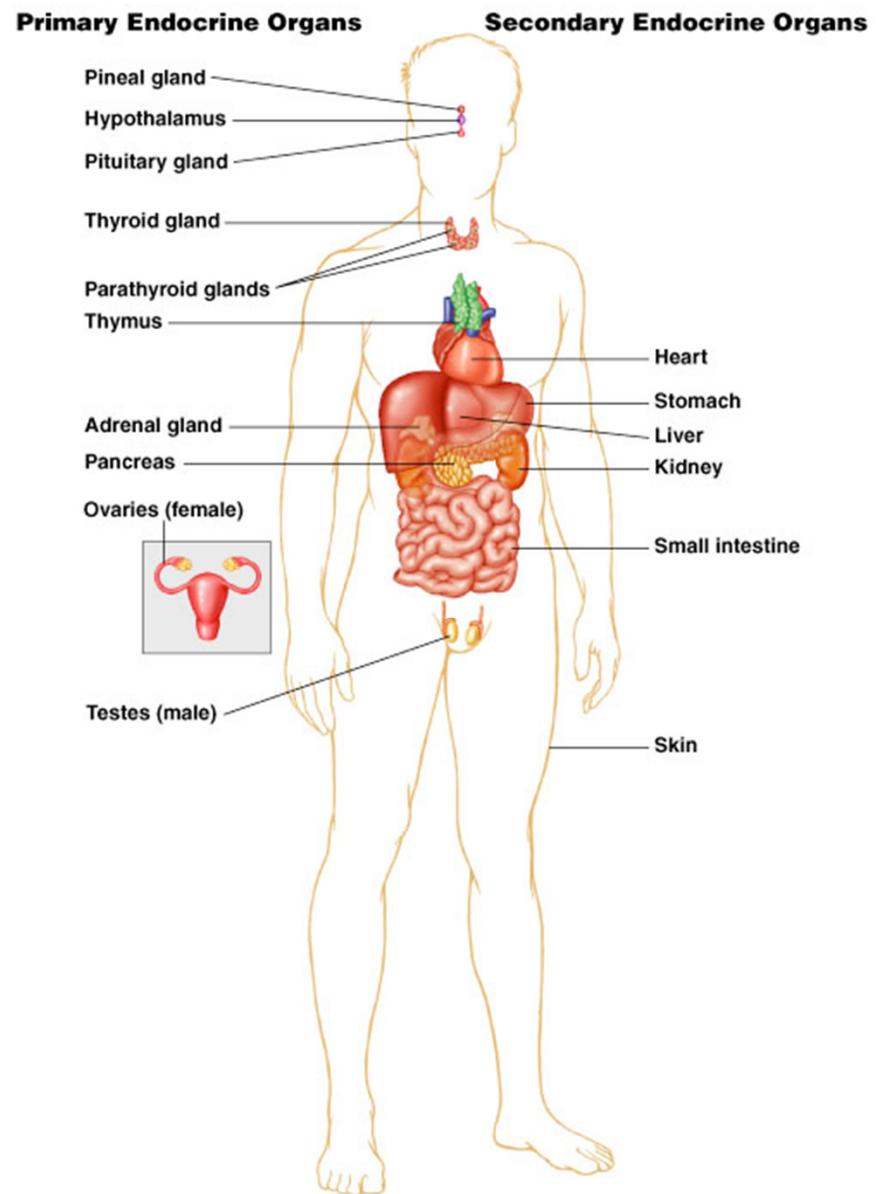
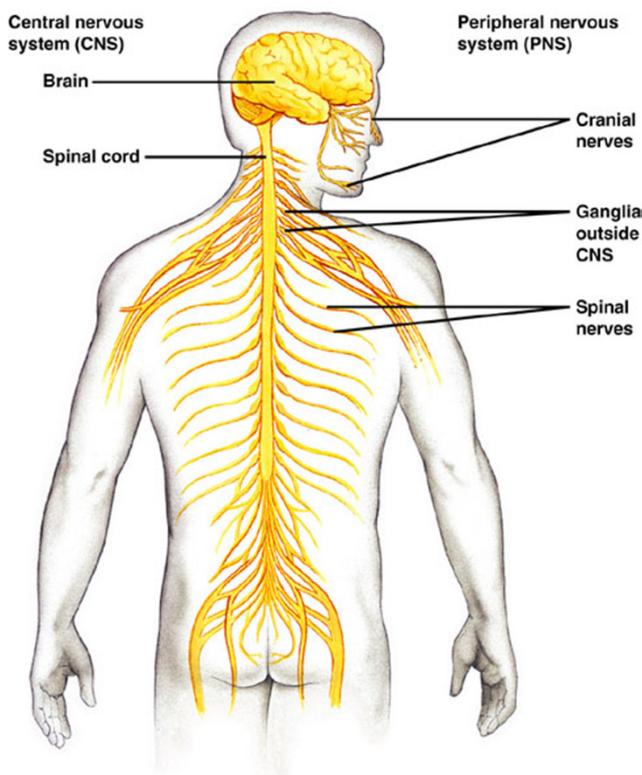


**Fig. 1.** Behavioral responses and fairness judgments (means  $\pm$  SEM) related to the most unfair offer of CHF 4 in the human offer condition. (A) Acceptance rates across treatment groups. Subjects whose right DLPFC is disrupted exhibit a much higher acceptance rate than those in the other two treatment groups (Mann-Whitney  $U$  tests, two-tailed,  $P < 0.05$ ). (B) Perceived unfairness across treatments (1 = very unfair; 7 = very fair). Subjects in all three treatment groups perceive an offer of 4 as very unfair, and there are no significant differences across groups.

Knoch et al 2006



**Evolutionary basis of inequity aversion**

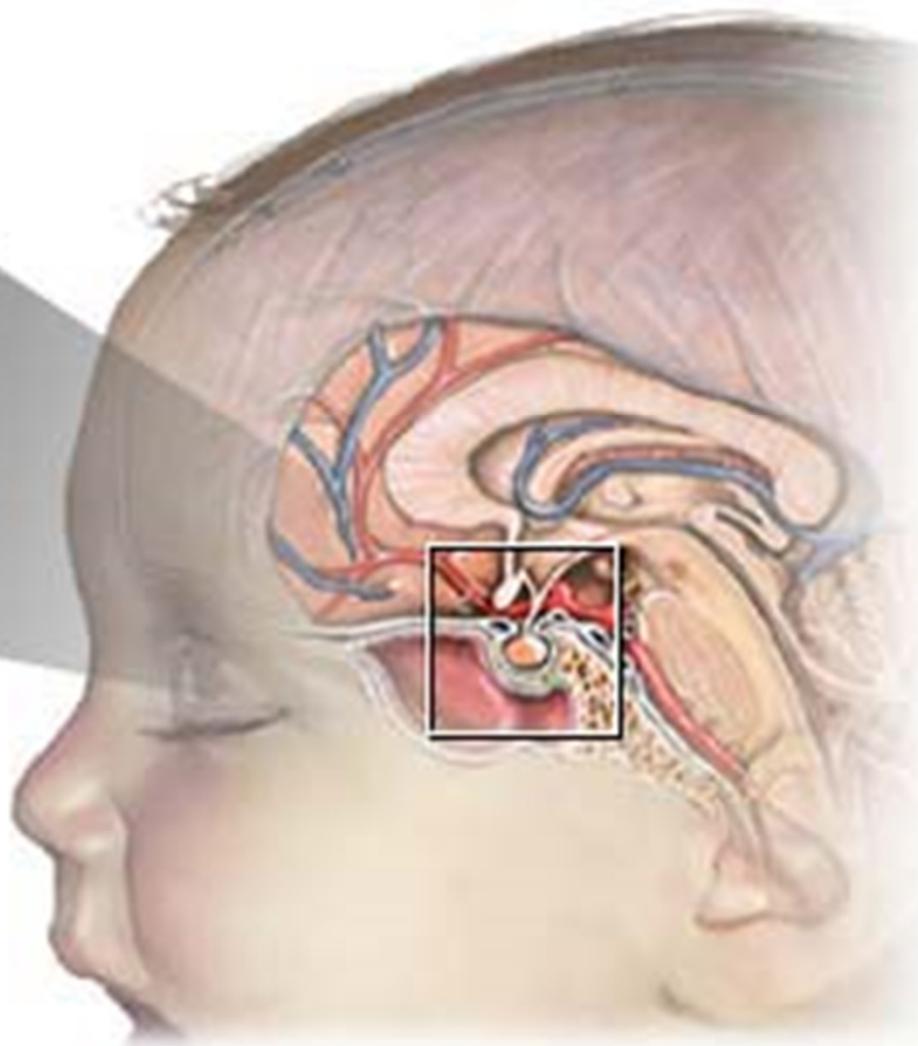
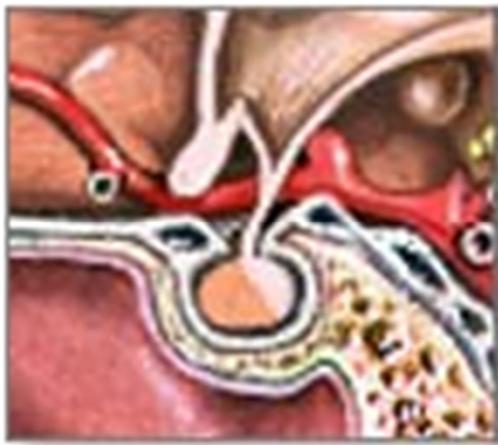


# Comparison of Nervous System and Endocrine System

▲ TABLE 4-3

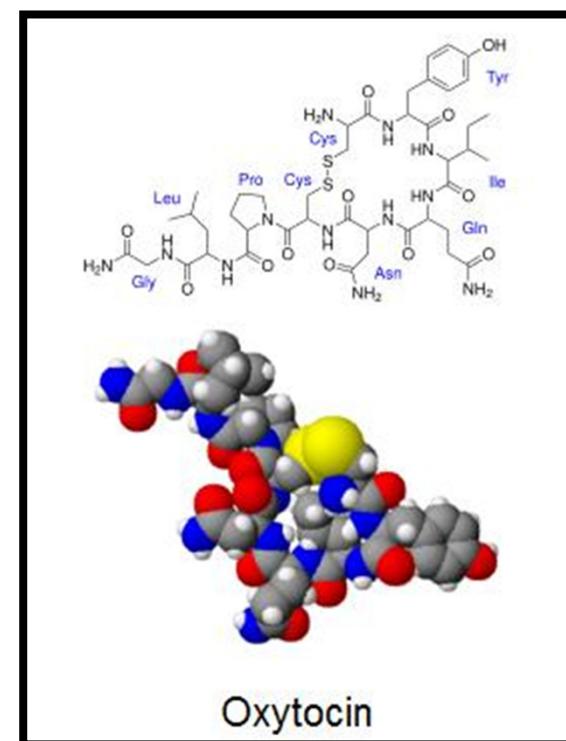
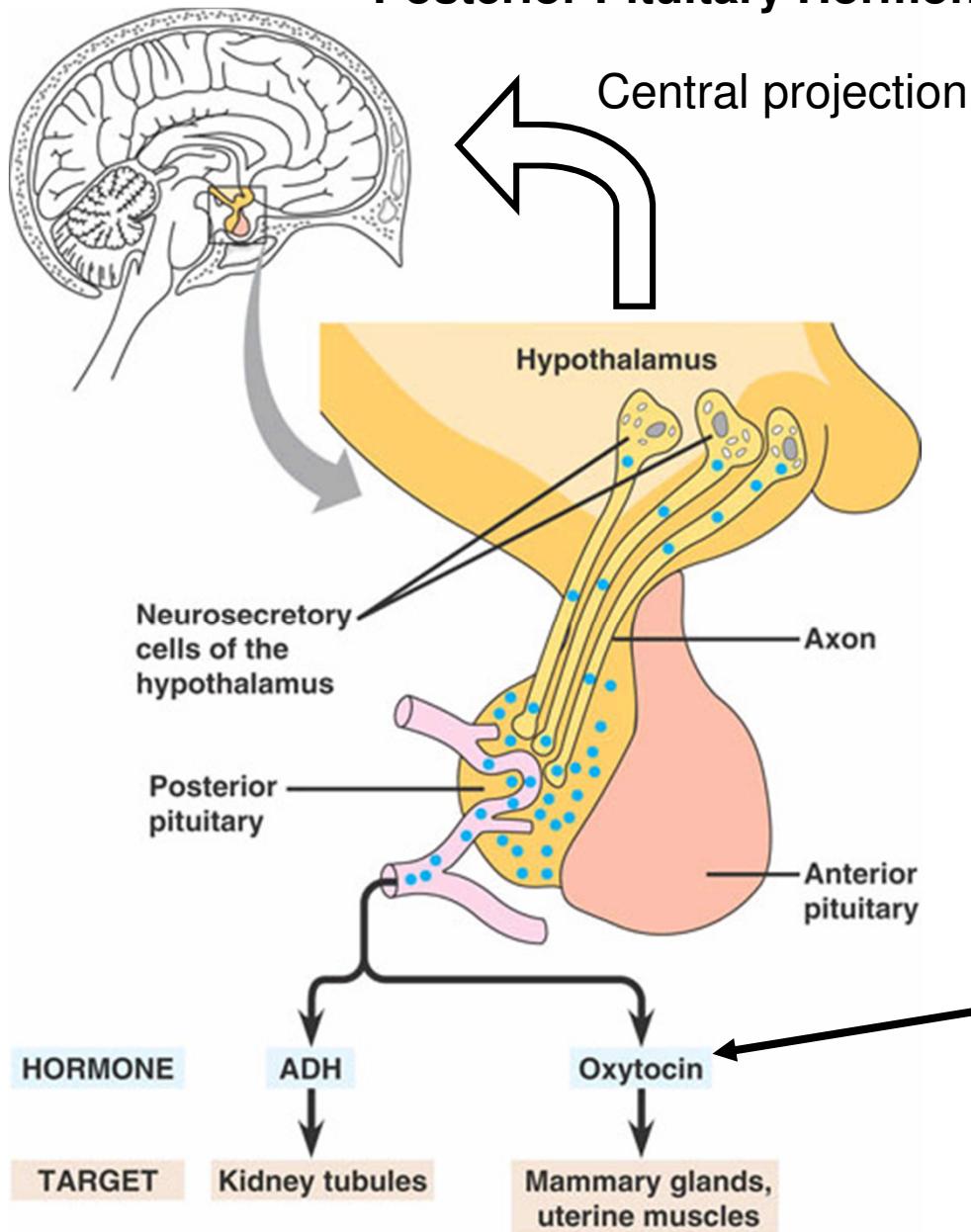
Comparison of the Nervous System and the Endocrine System

PROPERTY	NERVOUS SYSTEM	ENDOCRINE SYSTEM
<b>Anatomic Arrangement</b>	A “wired” system; specific structural arrangement between neurons and their target cells; structural continuity in the system	A “wireless” system; endocrine glands widely dispersed and not structurally related to one another or to their target cells
<b>Type of Chemical Messenger</b>	Neurotransmitters released into synaptic cleft	Hormones released into blood
<b>Distance of Action of Chemical Messenger</b>	Very short distance (diffuses across synaptic cleft)	Long distance (carried by blood)
<b>Means of Specificity of Action on Target Cell</b>	Dependent on close anatomic relationship between nerve cells and their target cells	Dependent on specificity of target cell binding and responsiveness to a particular hormone
<b>Speed of Response</b>	Rapid (milliseconds)	Slow (minutes to hours)
<b>Duration of Action</b>	Brief (milliseconds)	Long (minutes to days or longer)
<b>Major Functions</b>	Coordinates rapid, precise responses	Controls activities that require long duration rather than speed



The pituitary secretes hormones that are essential to growth and reproduction

## Posterior Pituitary Hormone Production and Release:



# Oxytocin

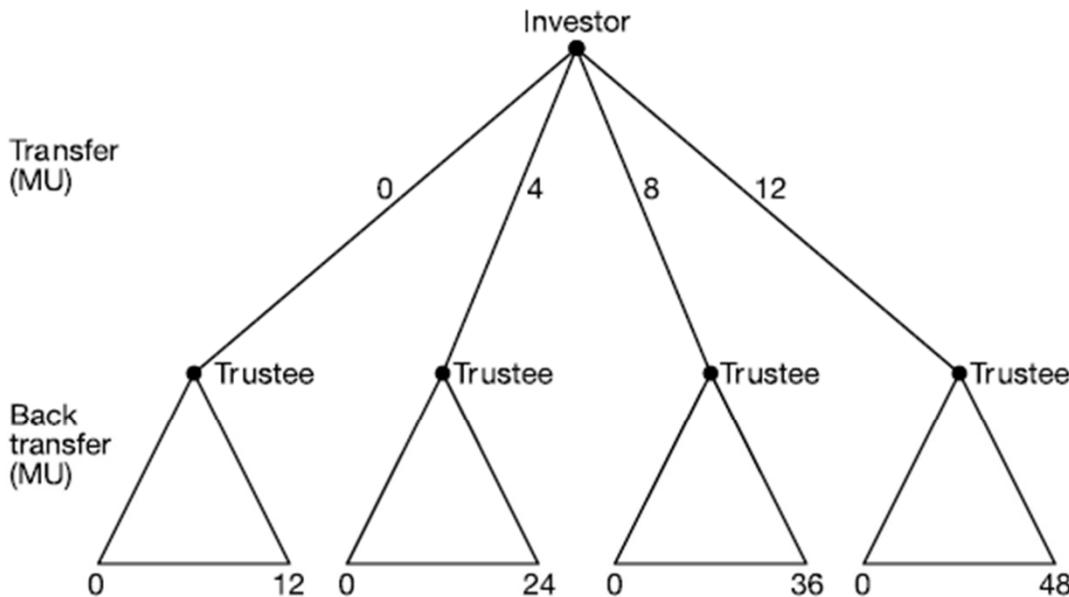
In humans, plasma levels of oxytocin have been related to :

- warm contact with a partner,
- gaps in social relationships,
- male and female sexual responses,
- and trust and trustworthiness during financial decisions!



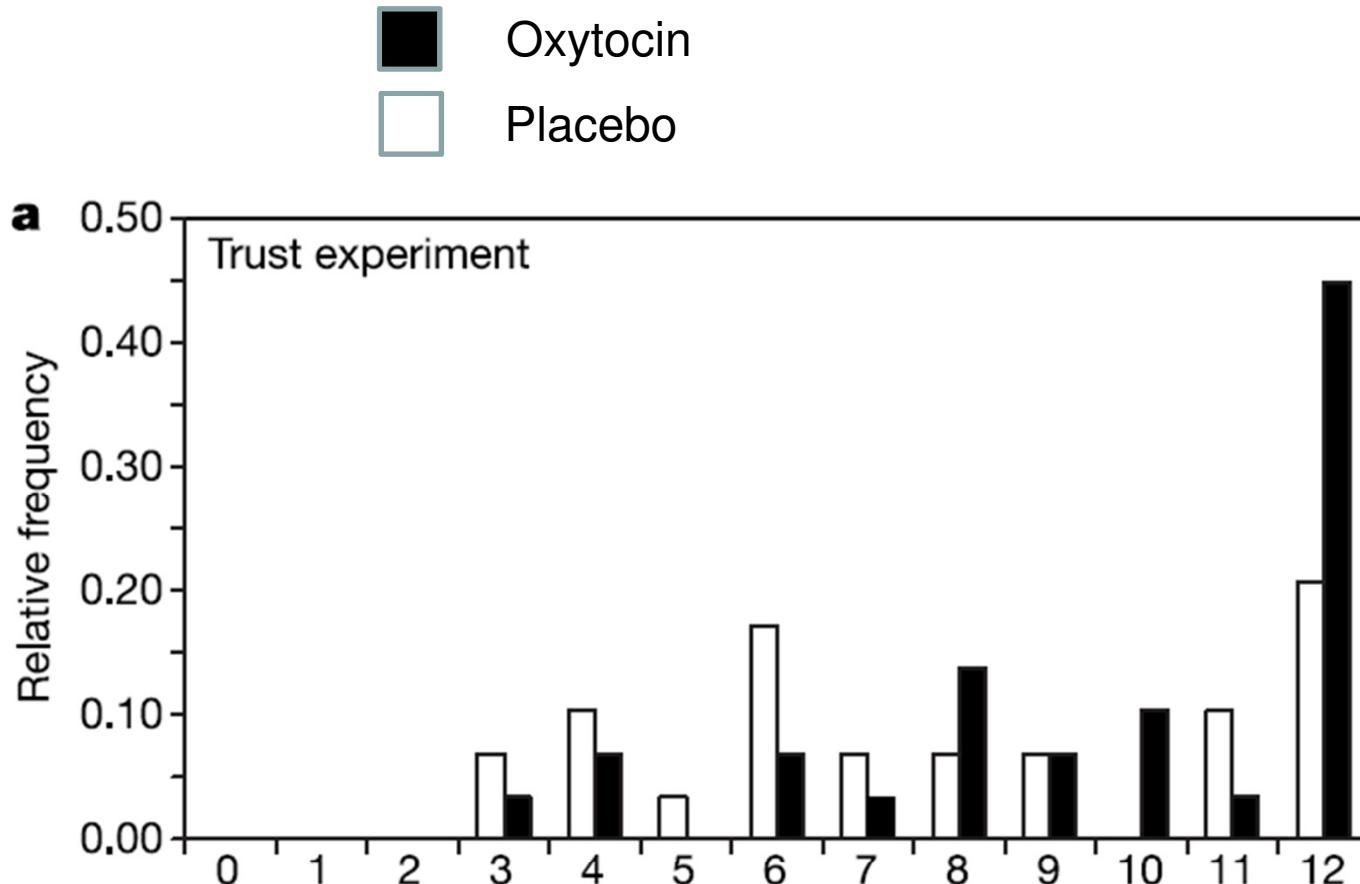
*Paul J. Zak* is Professor of Economics





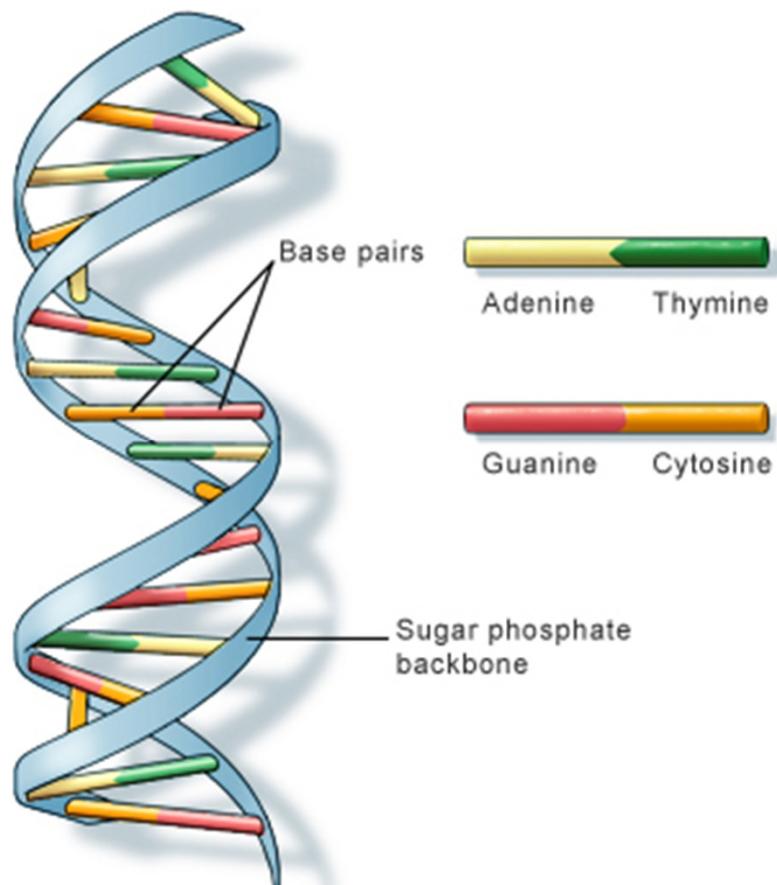
**Figure 1 | The trust game.** Both subjects receive an initial endowment of 12 monetary units (MU). The investor can send 0, 4, 8 or 12 MU to the trustee. The experimenter triples each MU the investor transfers. After the investor's decision is made, the trustee is informed about the investor's transfer. Then the trustee has the option of sending any amount between zero and his total amount available back to the investor. For example, if the investor has sent 12 MU, the trustee possesses 48 MU (12 MU own endowment + 36 MU tripled transfer) and can, therefore choose any back transfer from 0 to 48 MUs. The experimenter does not triple the back transfer. The investor's final payoff corresponds to the initial endowment minus the transfer to the trustee, plus the back transfer from the trustee. The trustee's final payoff is given by his initial endowment plus the tripled transfer of the investor, minus the back transfer to the investor. At the end of the experiment, the earned MU are exchanged into real money according to a publicly announced exchange rate (see Methods). Each subject made four decisions in the same player role while paired with four different, randomly selected interaction partners.

Kosfeld et al 2005



**Figure 2 | Transfers in the trust and the risk experiment.** Each observation represents the average transfer amount (in MU) over four transfer decisions per investor. **a**, Relative frequency of investors' average transfers in oxytocin (filled bars) and placebo (open bars) groups in the trust experiment ( $n = 58$ ). Subjects given oxytocin show significantly higher transfer levels.

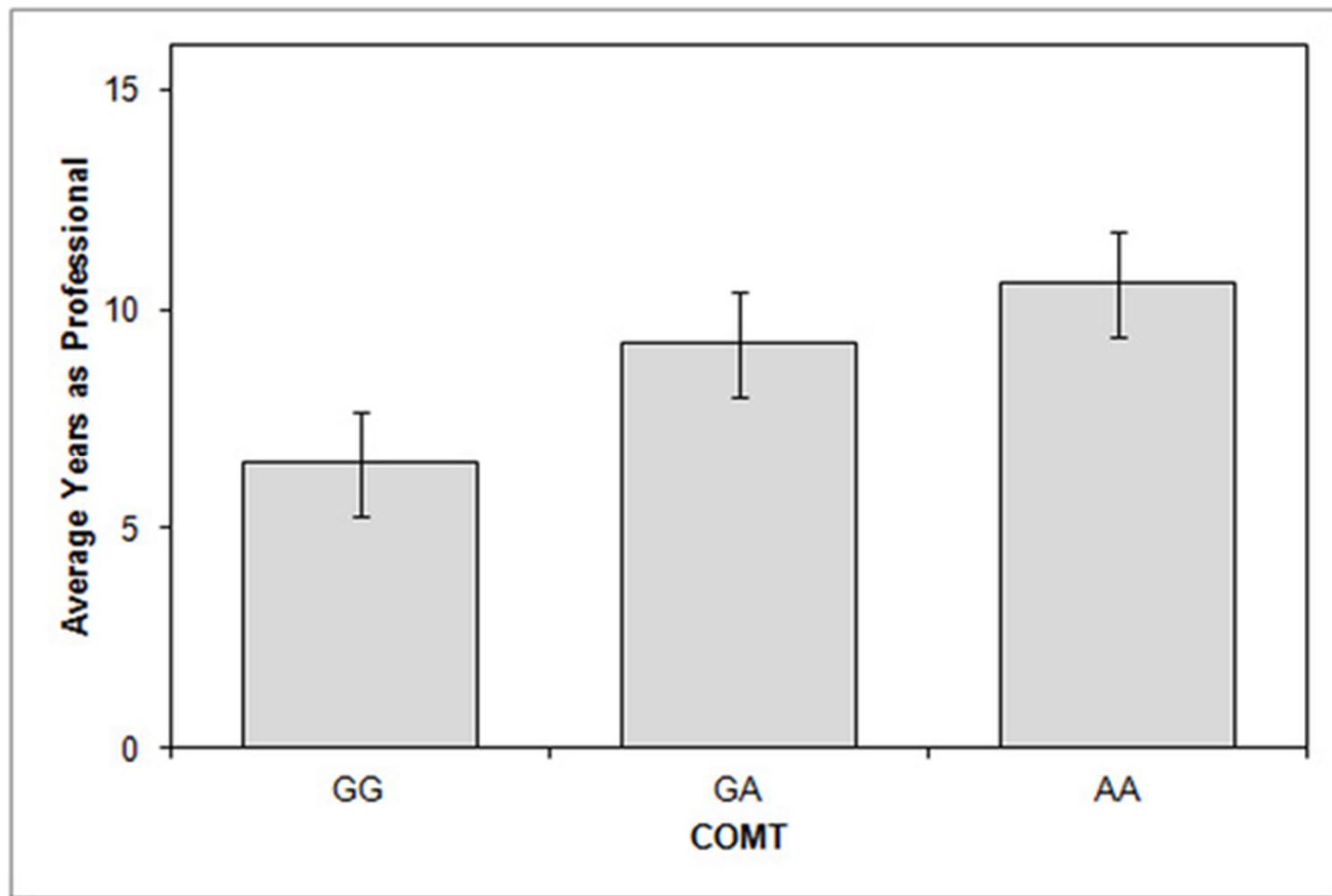
# Genetic influence on our decisions and behavior



U.S. National Library of Medicine

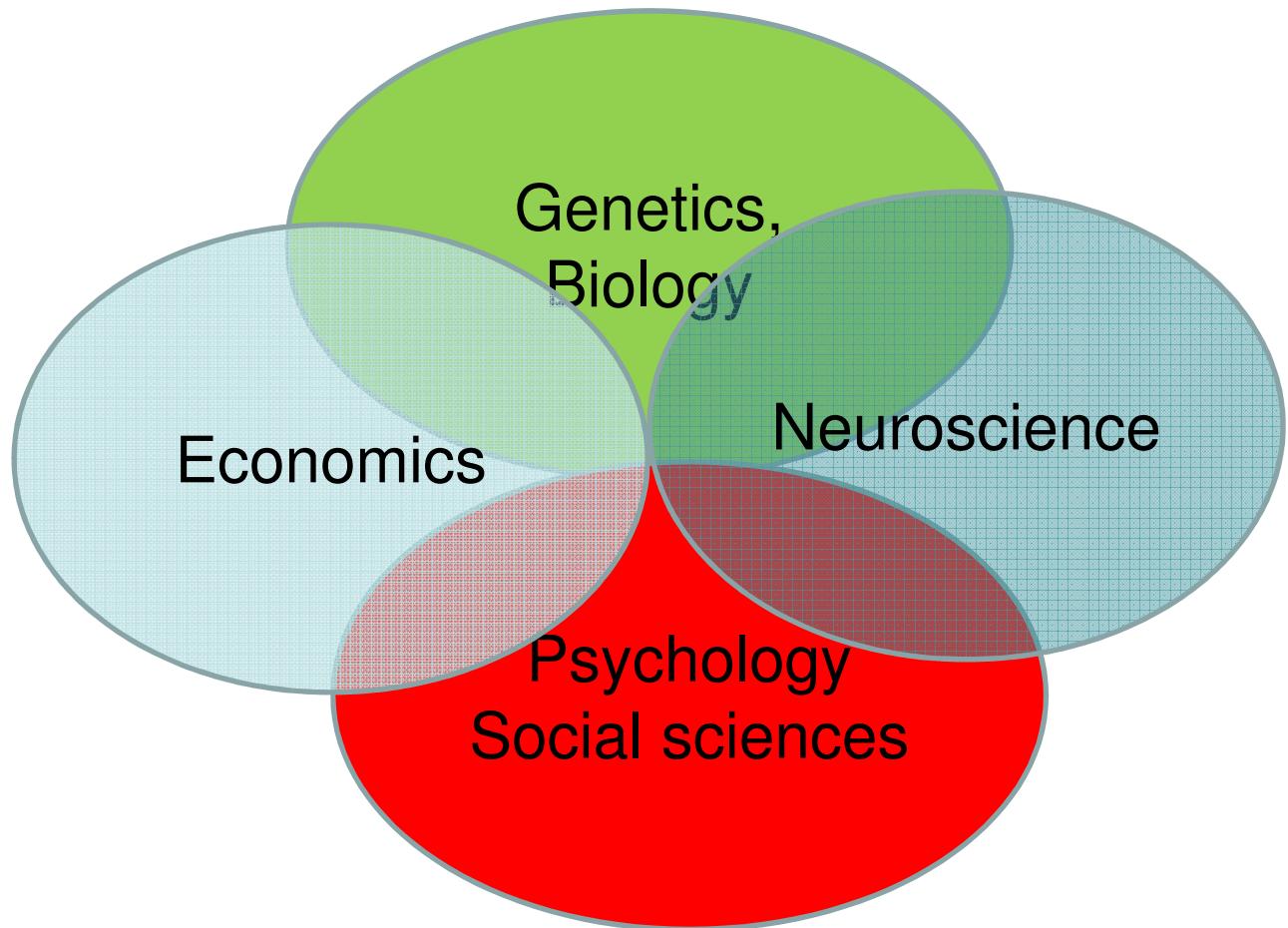
## Years working as a trader correlates with DA levels as determined by COMT alleles

These alleles are associated with moderate, rather than very high or very low, levels of synaptic dopamine.

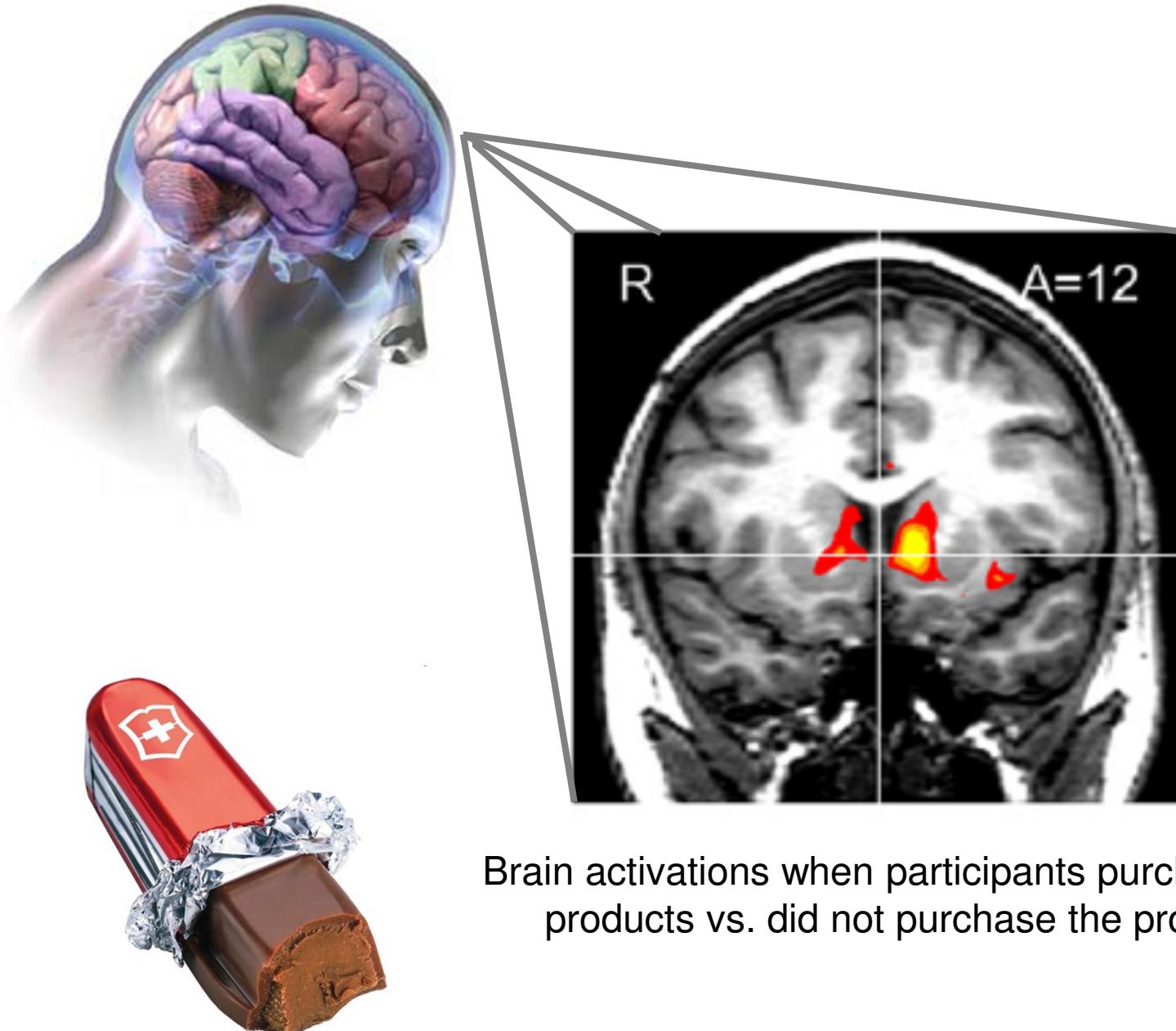


Sapra S, Beavin LE, Zak PJ (2012) A Combination of Dopamine Genes Predicts Success by Professional Wall Street Traders. PLoS ONE 7(1): e30844. doi:10.1371/journal.pone.0030844

<http://www.plosone.org/article/info:doi/10.1371/journal.pone.0030844>



# **Neuroeconomics**



Brain activations when participants purchased the products vs. did not purchase the products

Knutson et al 2005

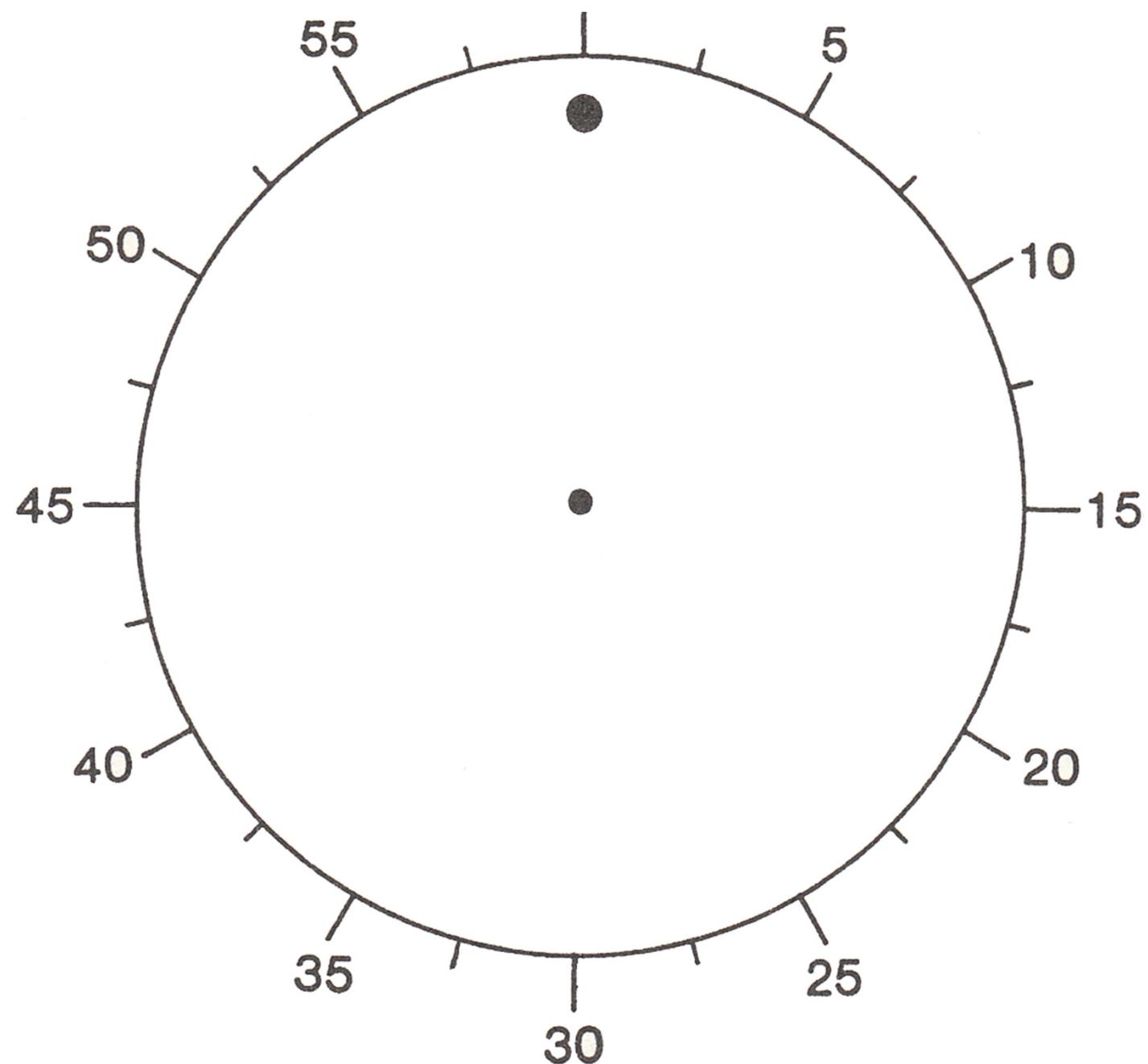


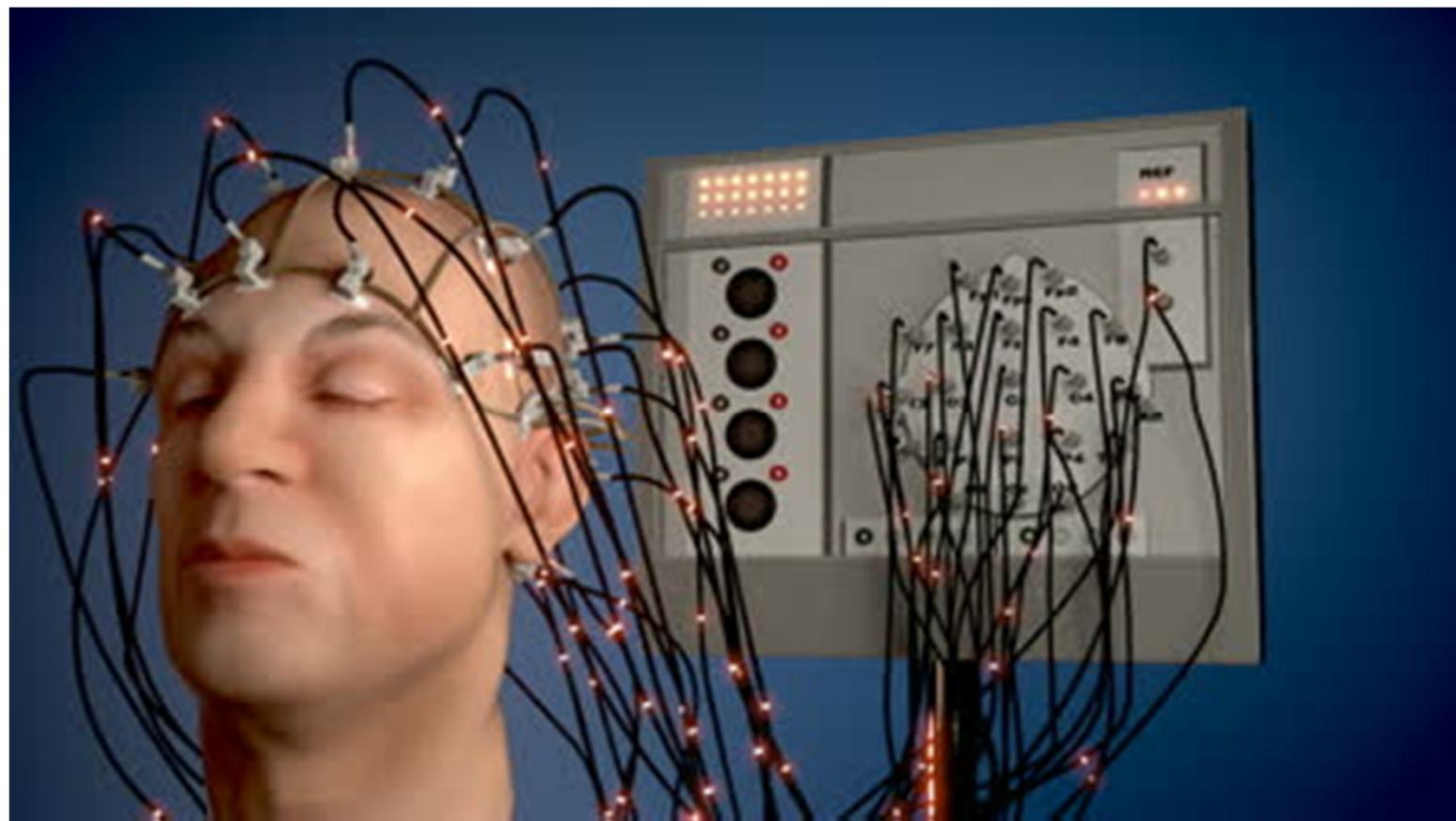


Benjamin Libet  
(1916-2007)

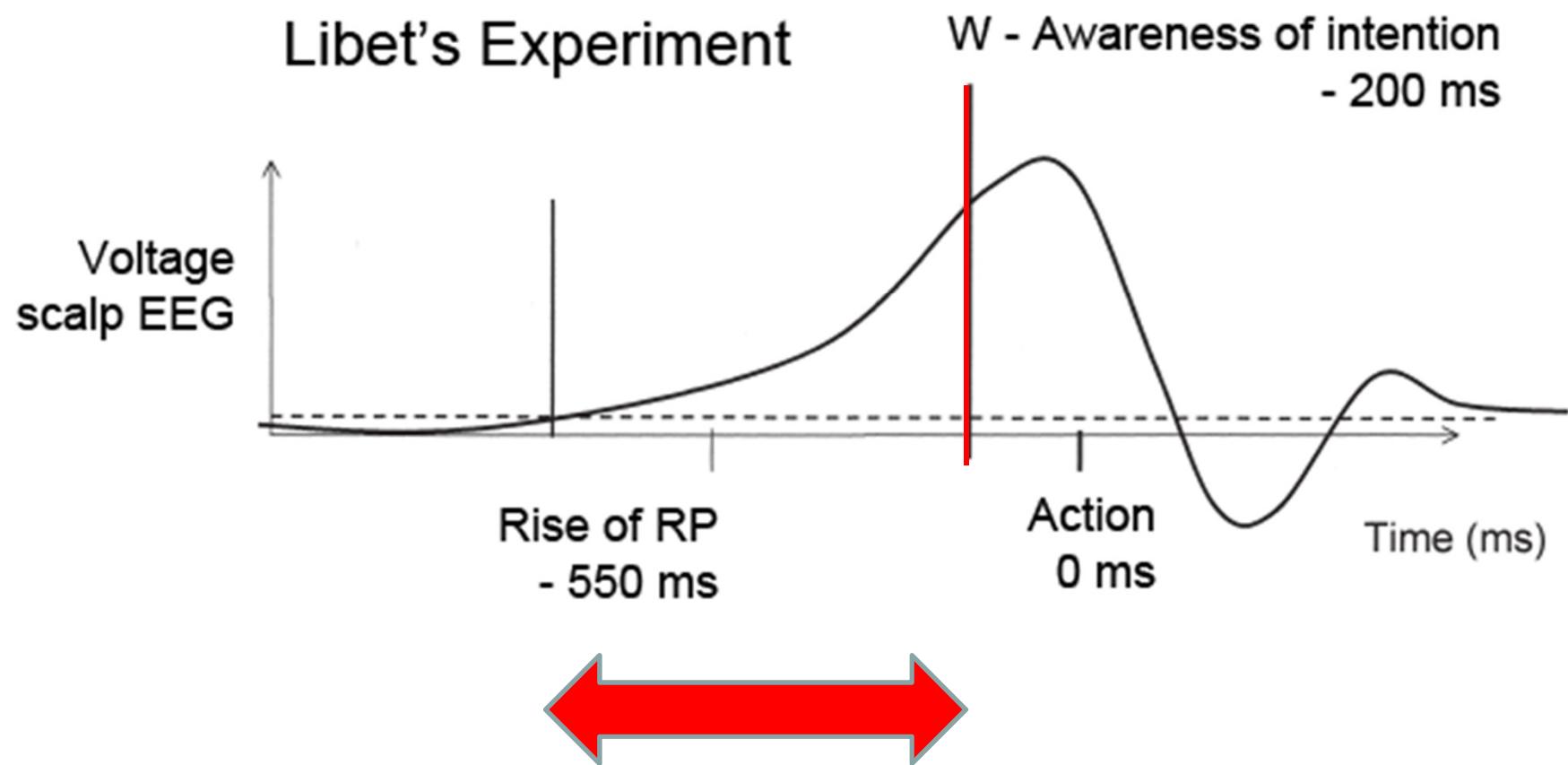
University of California

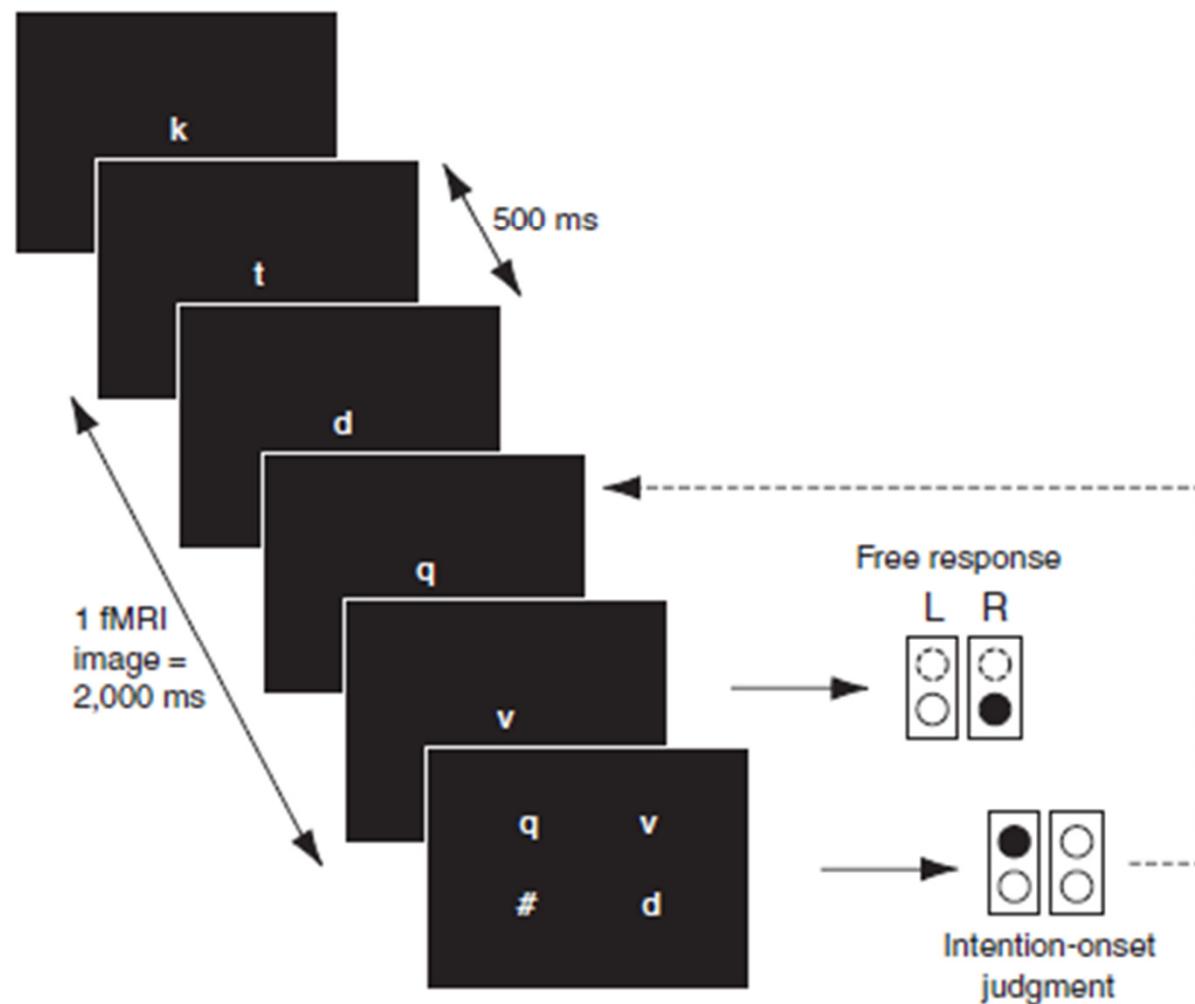
Libet, Benjamin; Gleason, Curtis A.; Wright, Elwood W.; Pearl, Dennis K. (1983). "Time of Conscious Intention to Act in Relation to Onset of Cerebral Activity (Readiness-Potential) - The Unconscious Initiation of a Freely Voluntary Act". *Brain* **106**: 623–642.

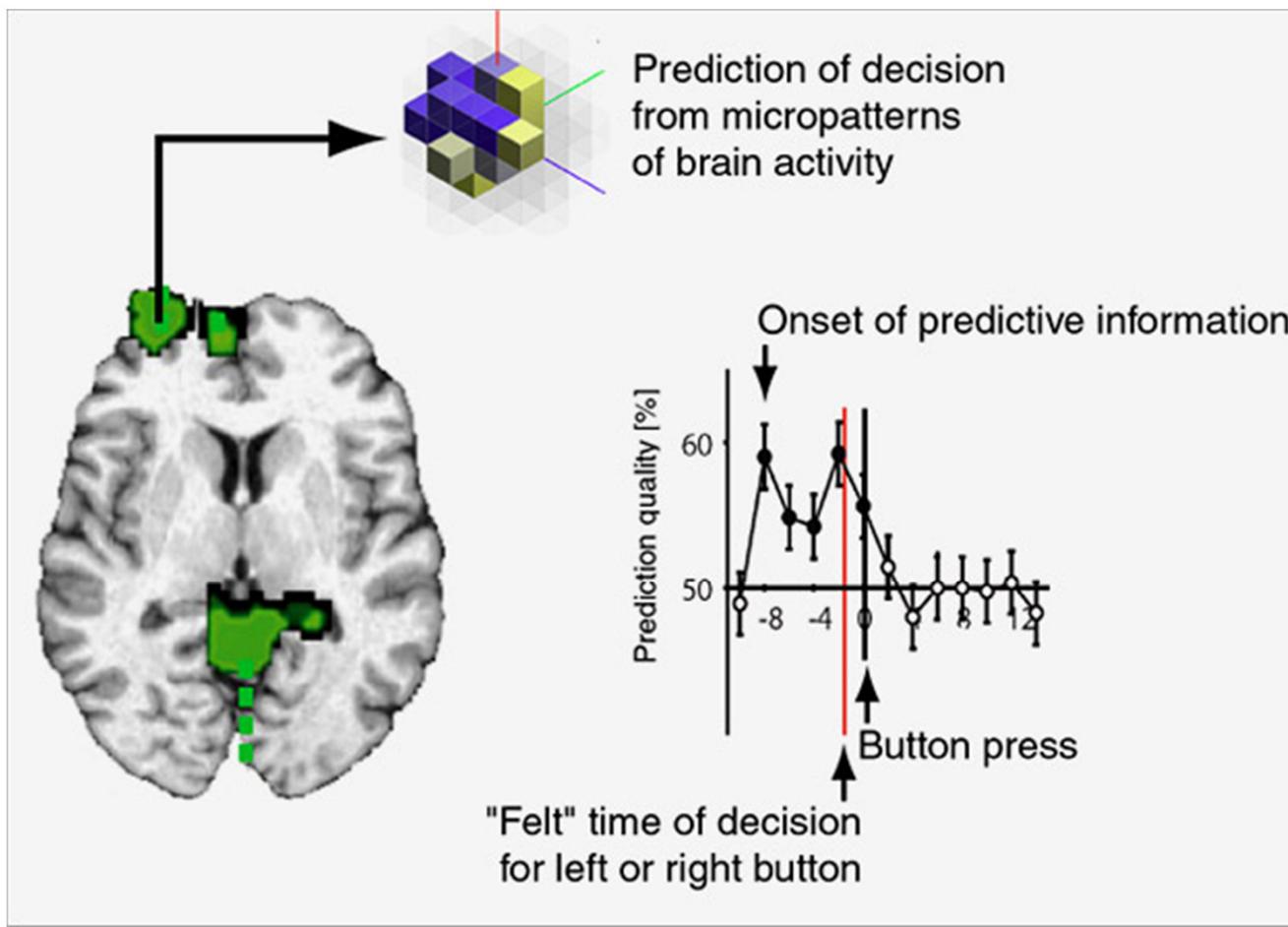




Dabarti CGI

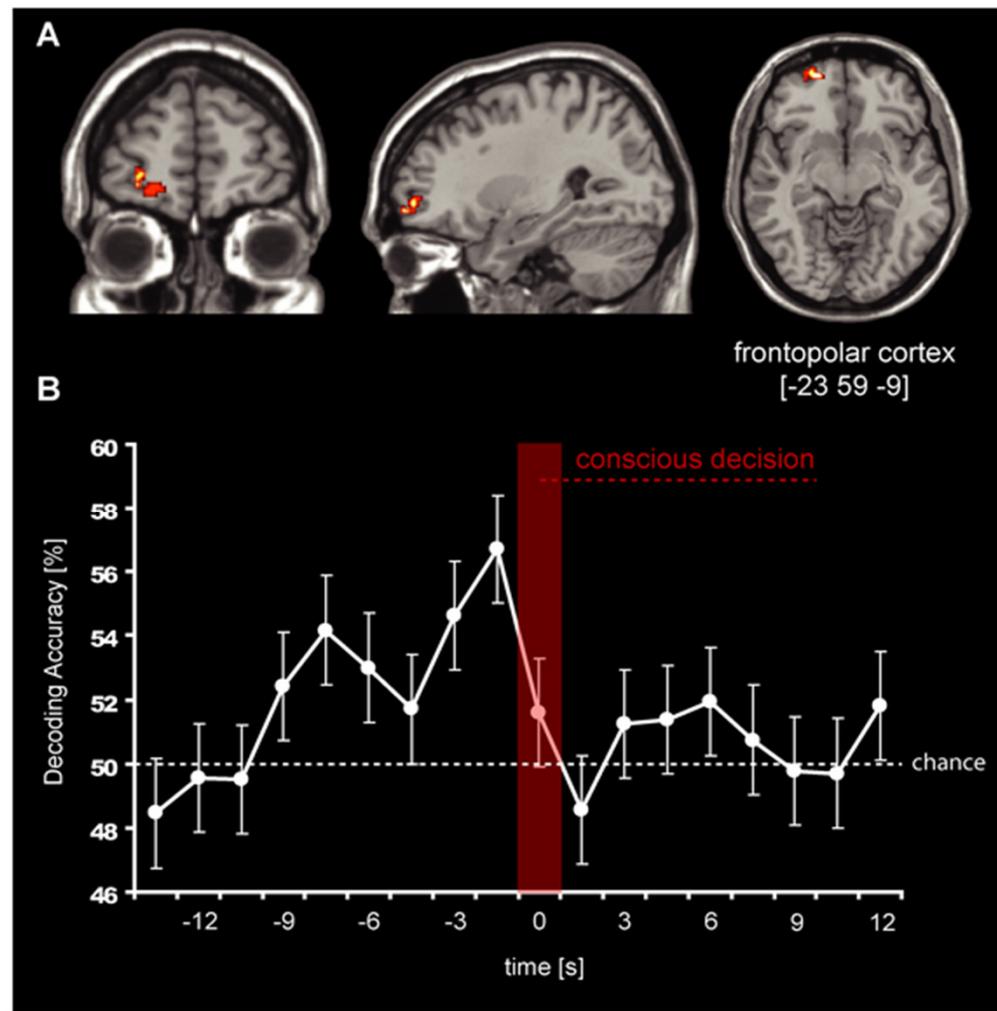






"Your decisions are strongly prepared by brain activity. By the time consciousness kicks in, most of the work has already been done," said study co-author John-Dylan Haynes

**Figure 3. Decoding of upcoming motor decisions from frontopolar cortex.**



Bode S, He AH, Soon CS, Trampel R, et al. (2011) Tracking the Unconscious Generation of Free Decisions Using Ultra-High Field fMRI. PLoS ONE 6(6): e21612. doi:10.1371/journal.pone.0021612

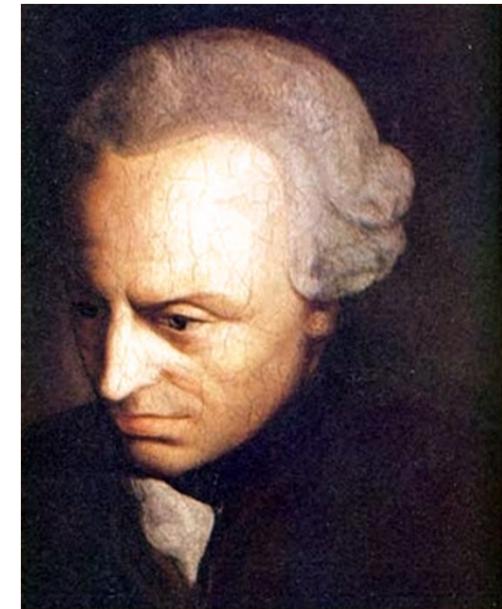
<http://www.plosone.org/article/info:doi/10.1371/journal.pone.0021612>



**Martin Luther**  
(1483–1546)



**Benedict de Spinoza**  
(1632 –1677)



**Immanuel Kant**  
(1724 –1804)

...men are deceived in thinking themselves free...  
So this - their not knowing any cause of their  
actions - is their idea of freedom!

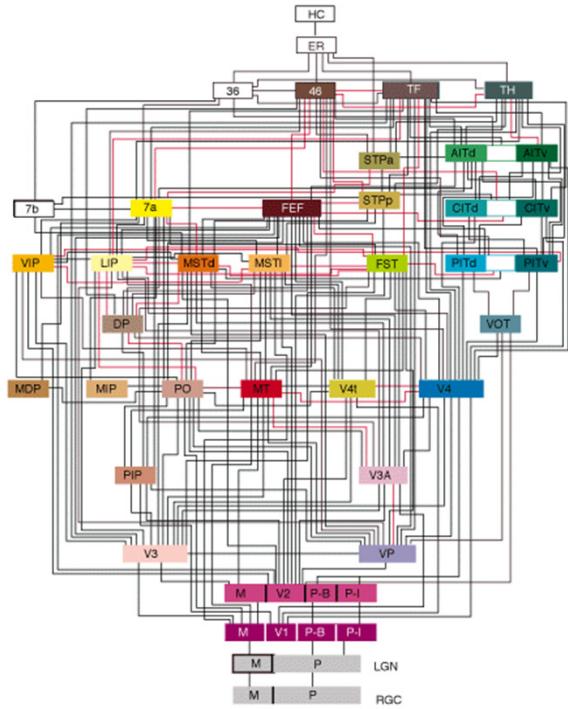
Benedict de Spinoza



**Martin Luther**  
(1483–1546)



**Benedict de Spinoza**  
(1632 –1677 )



**Visual system by  
Felleman and Van Essen  
(1991)**

...men are deceived in thinking themselves free...  
So this - their not knowing any cause of their  
actions - is their idea of freedom!

Benedict de Spinoza

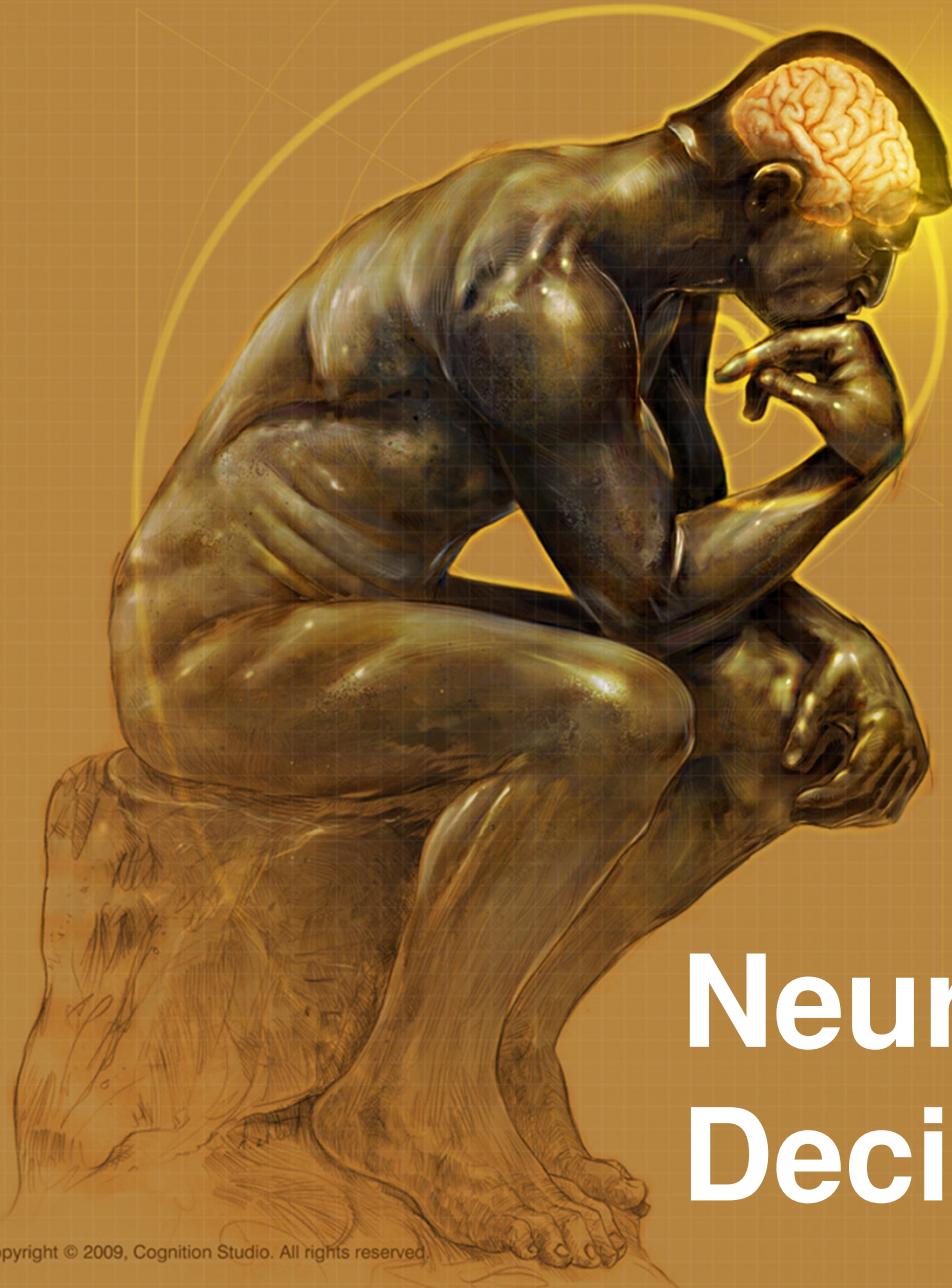


26% of all manipulated trials were caught by the subjects - “choice blindness”.

Petter Johansson

7 OCTOBER 2005 VOL 310 SCIENCE

Type	%		
Specific Conf.	13.3		She's radiant. I would rather have approached her at a bar than the other one. I like earrings! [M]
Detailed Conf.	17.3	She looks like an aunt of mine I think, and she seems nicer than the other one. [F]	
Emotional Conf.	9.3		Yes, well, [laughter] she looks very hot in this picture. [M]

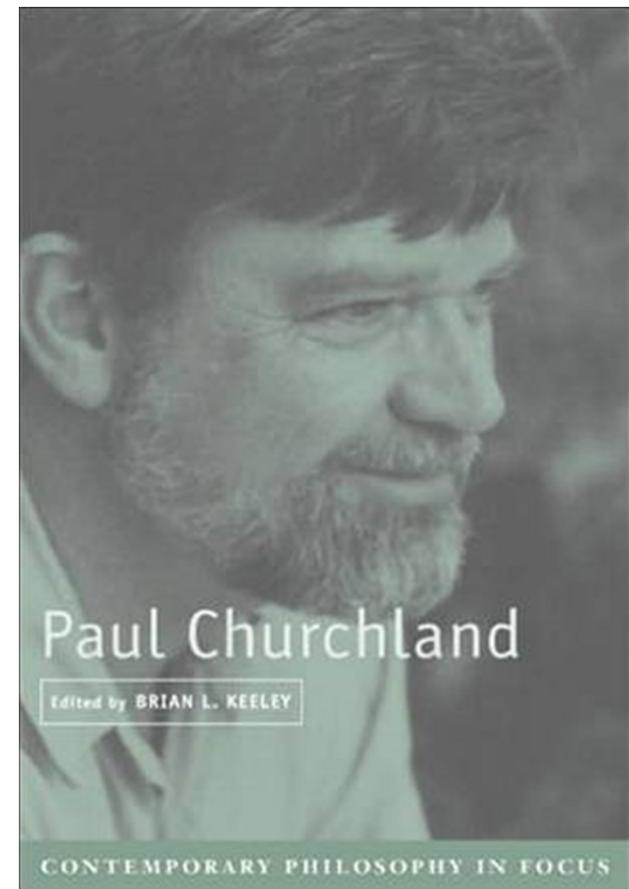


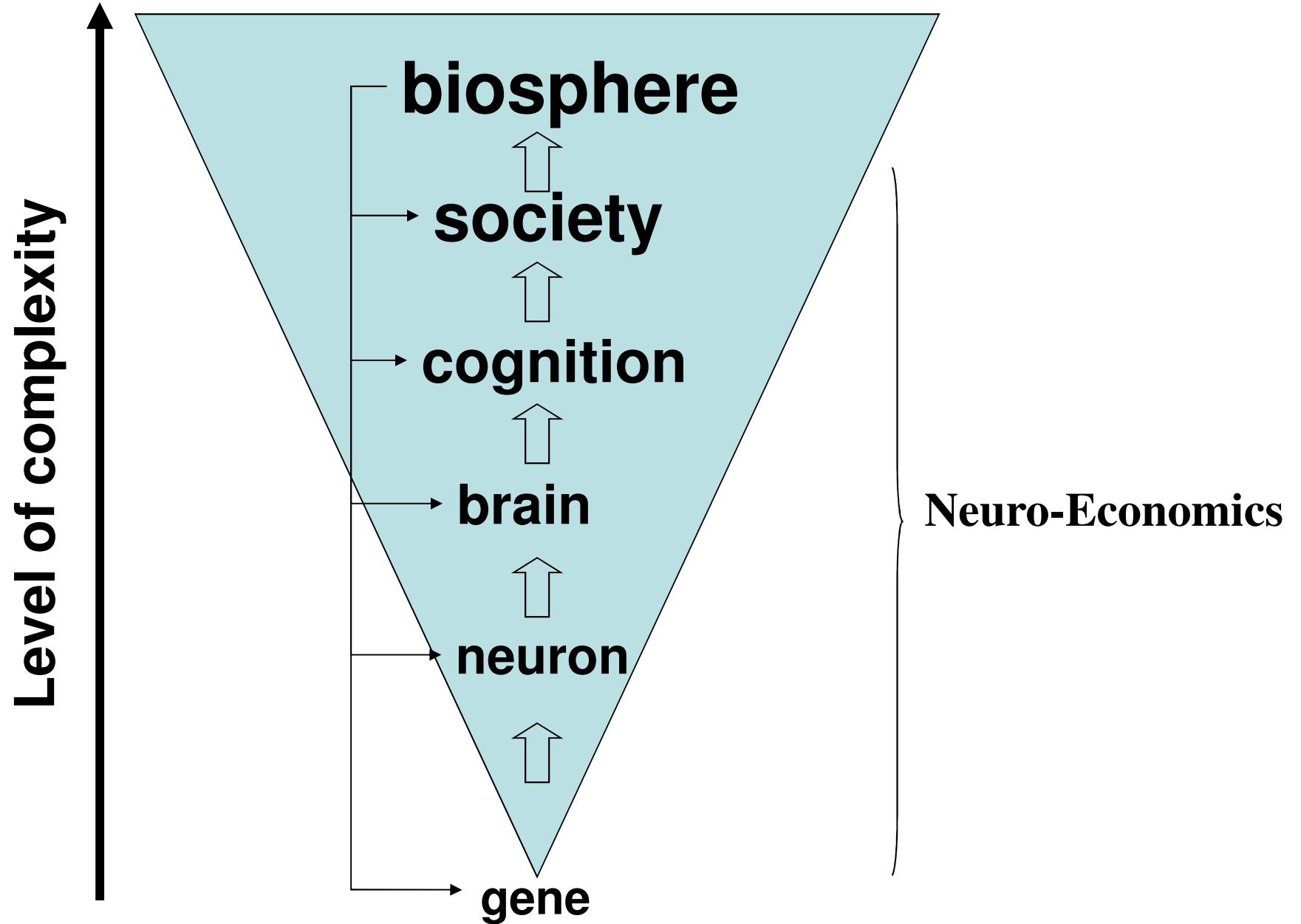
# Neuroscience of Decision making

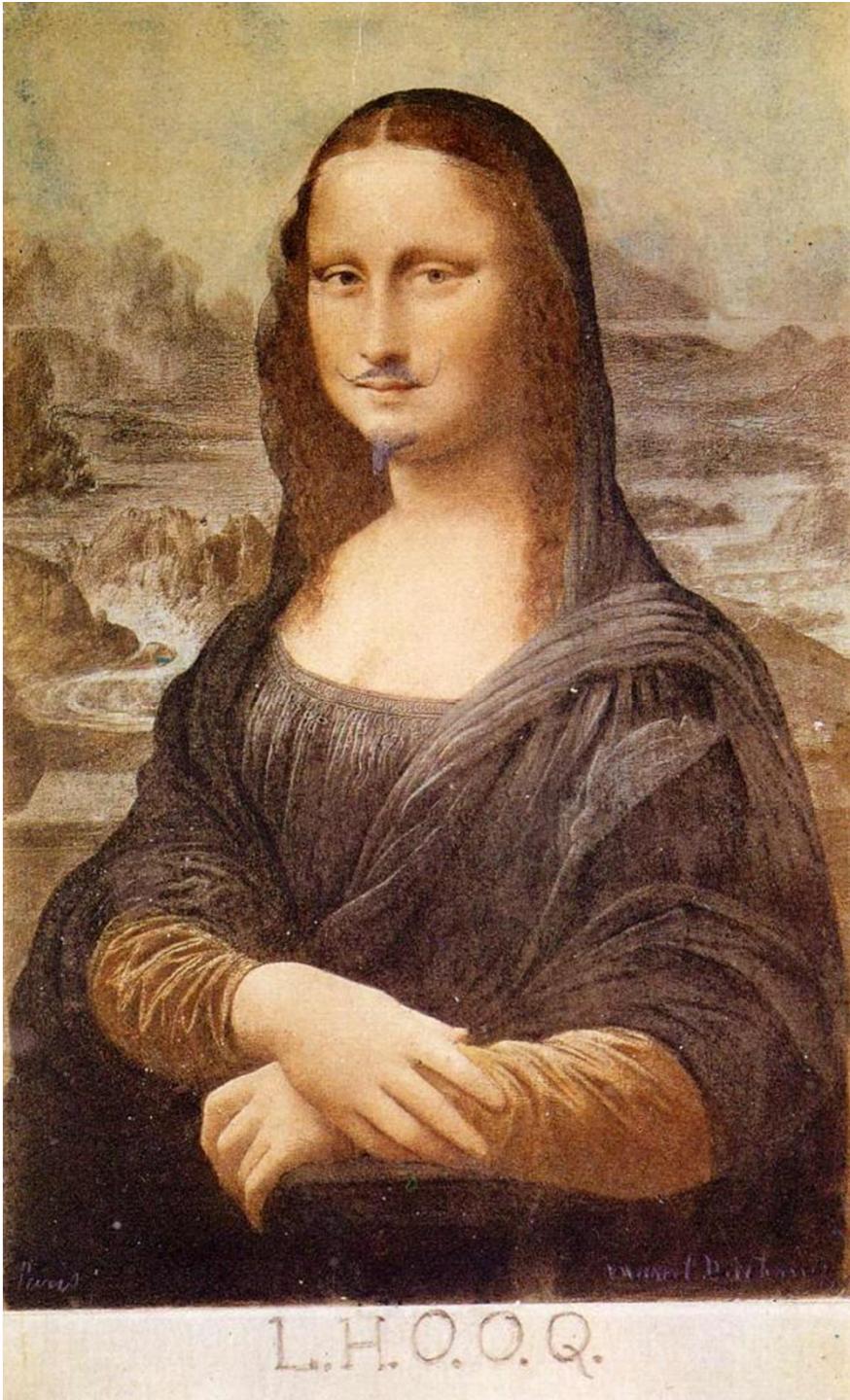
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# Eliminative materialism

...our common-sense conception of psychological phenomena constitutes a radically false theory, a theory so fundamentally defective that theory will eventually be displaced, rather than smoothly reduced, by completed neuroscience.







**readymades**  
**L.H.O.O.Q.**  
by Marcel Duchamp



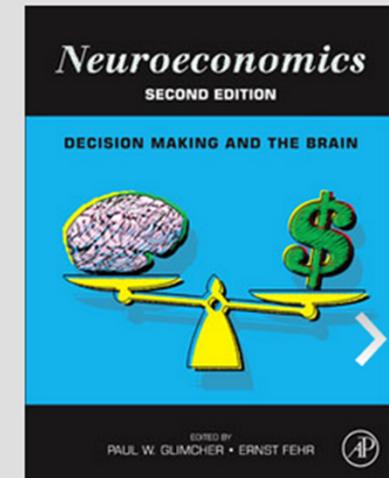
# Society for NeuroEconomics

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Neuroeconomics: Decision Making and the Brain, 2e. The 2nd edition of this handbook, featuring many members of the Society for Neuroeconomics as authors, is available for pre-order. Members can get a discount code.



**Decisions, Uncertainty, and the Brain**  
The Science of Neuroeconomics



Paul W. Glimcher

# *Neuroeconomics*

DECISION MAKING AND THE BRAIN



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