Scientific Philosophy

Grupo de Astrofísica Relativista
y Radiastronomía

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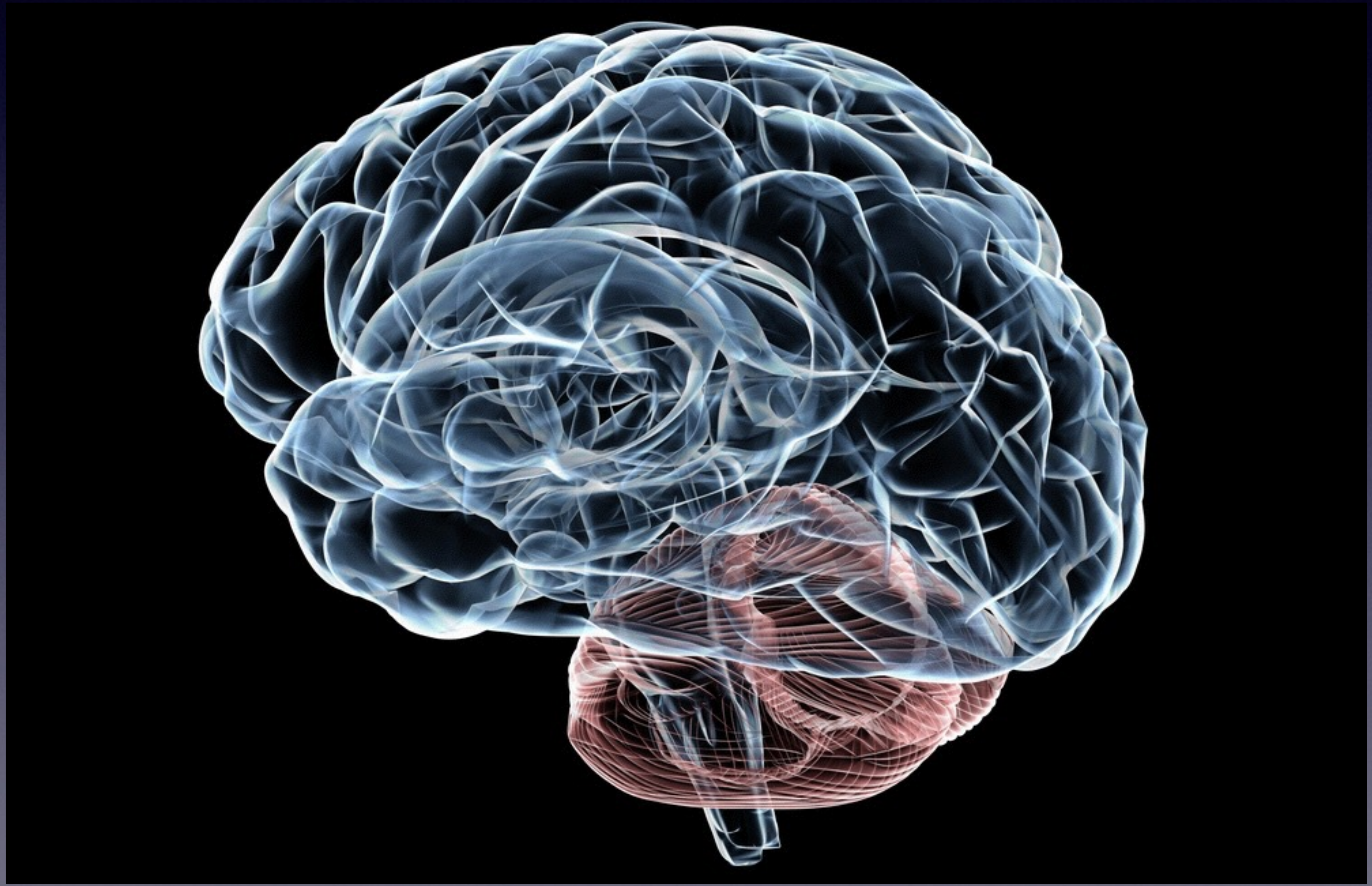
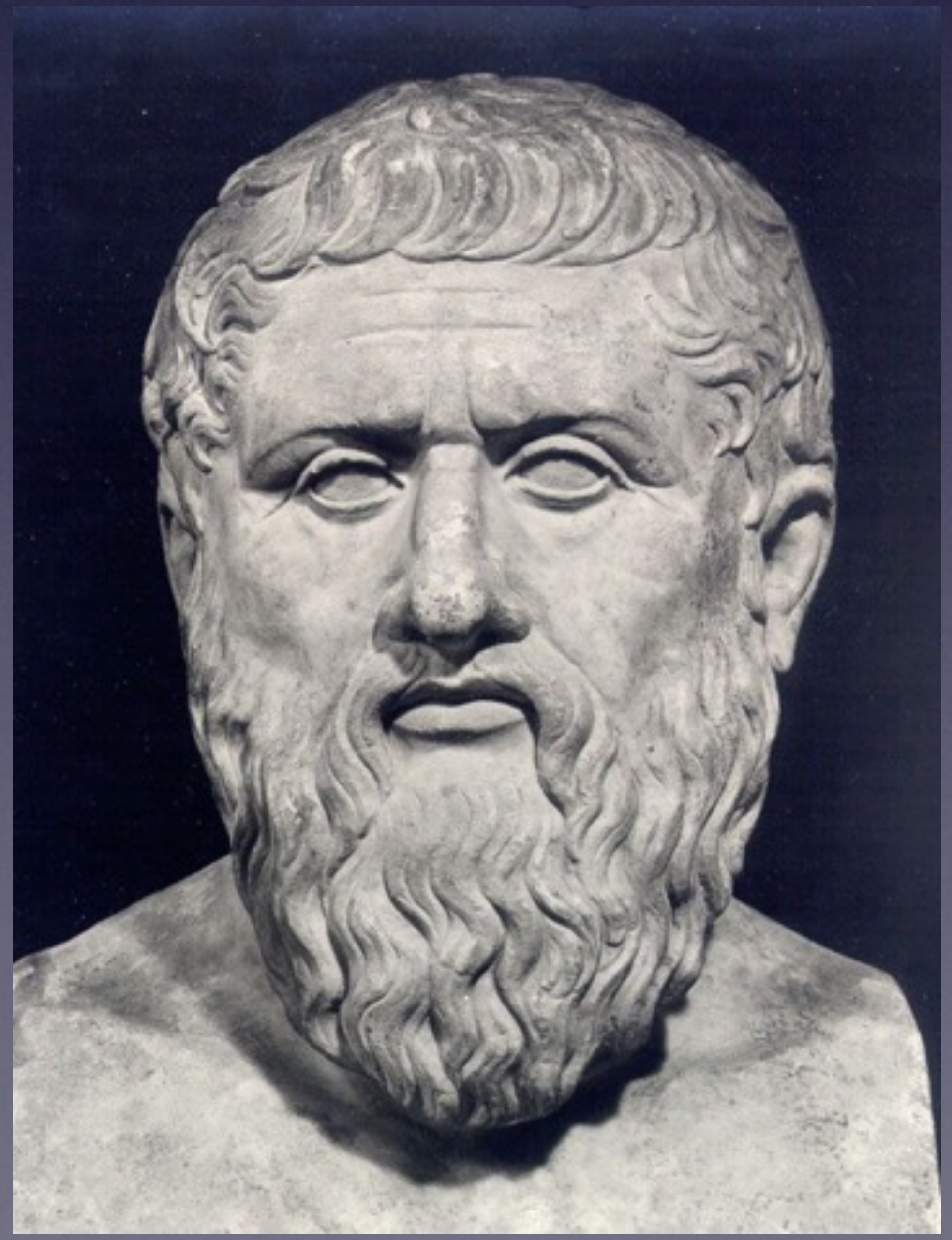
Epistemology



Episteme, as distinguished from techne, is etymologically derived from the Ancient Greek word ἐπιστήμη for knowledge or science, which comes from the verb ἐπίσταμαι, "to know". In Plato's terminology episteme means knowledge, as in "justified true belief", in contrast to doxa, common belief or opinion. The word epistemology, meaning the study of knowledge, is derived from episteme.



Plato

Epistemology is the general study of cognitive processes and their outcome: ***knowledge***.

Knowledge is the product of cognitive operations made by an inquiring subject. It is not a thing or a substance, but a series of brain changes in the knower. Knowledge is not independent of the knowing subject, although we often feign it is for practical reasons.

Knowledge is different from ***belief***: I can know a story, for instance, but do not believe it. Belief implies a psychological adherence to some propositions. It is possible to believe something without understanding it, so belief is not necessary associated with neither truth nor justification.

Knowledge acquisition requires a modification of the brain of the knower. This can be done in different ways, hence there are different kinds of knowledge.

(i) ***Sensory-motor knowledge***: the result of learning from actions.
(ii) ***Perceptual knowledge***: the result of perceiving events, either internal or external to the subject.
(iii) ***Conceptual or propositional knowledge***: the result of ideation, conjecturing, testing, correcting.

Notice that not all knowledge is beneficial: we can learn trivialities, falsehoods, or highly harmful habits

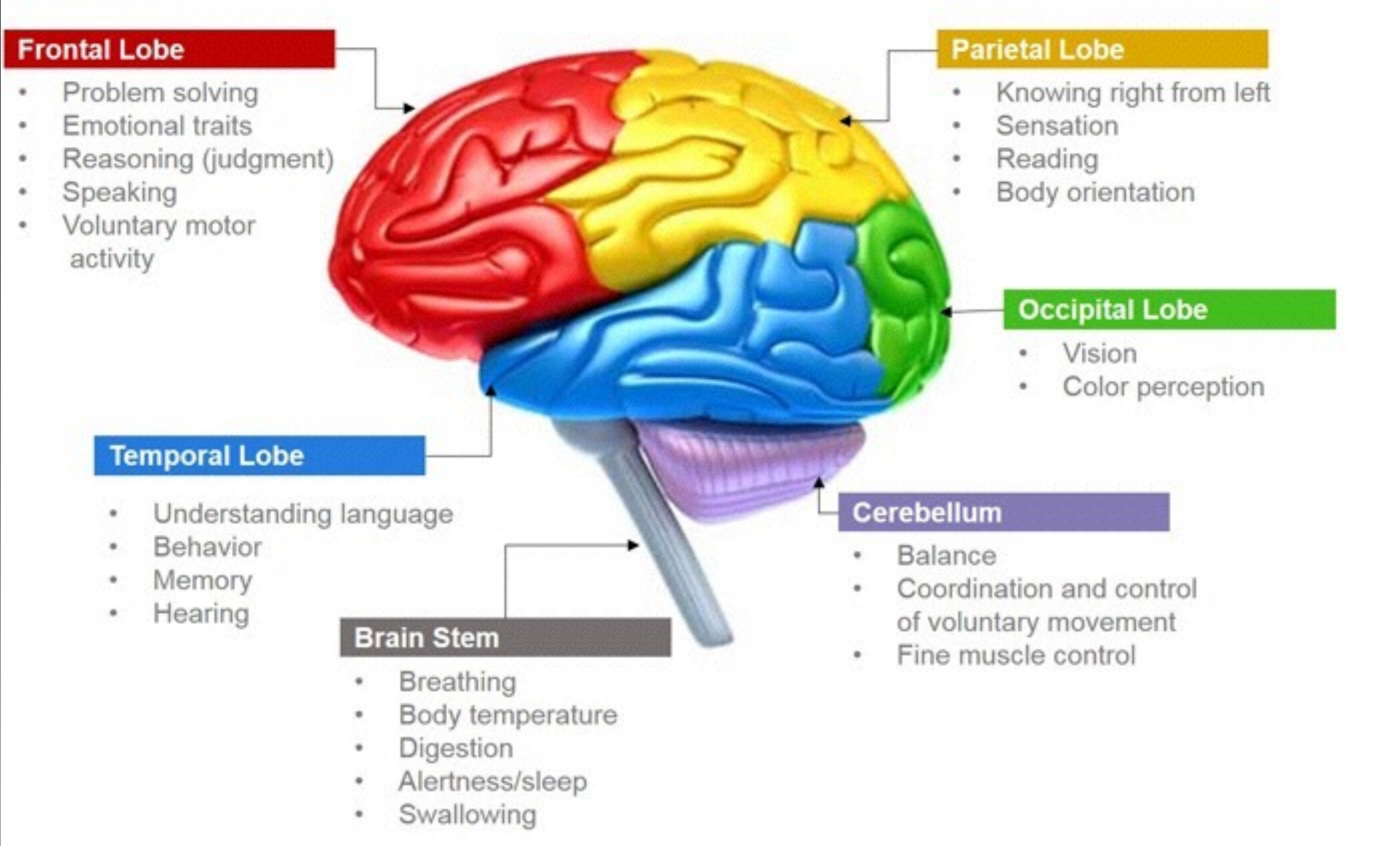
The three kind of knowledge are *interrelated*: conceptual knowledge can improve motor skills and perception; perception is used to evaluate conjectures; motor skills can help to improve perception and build instruments such as books, that enhance the ability to learn.

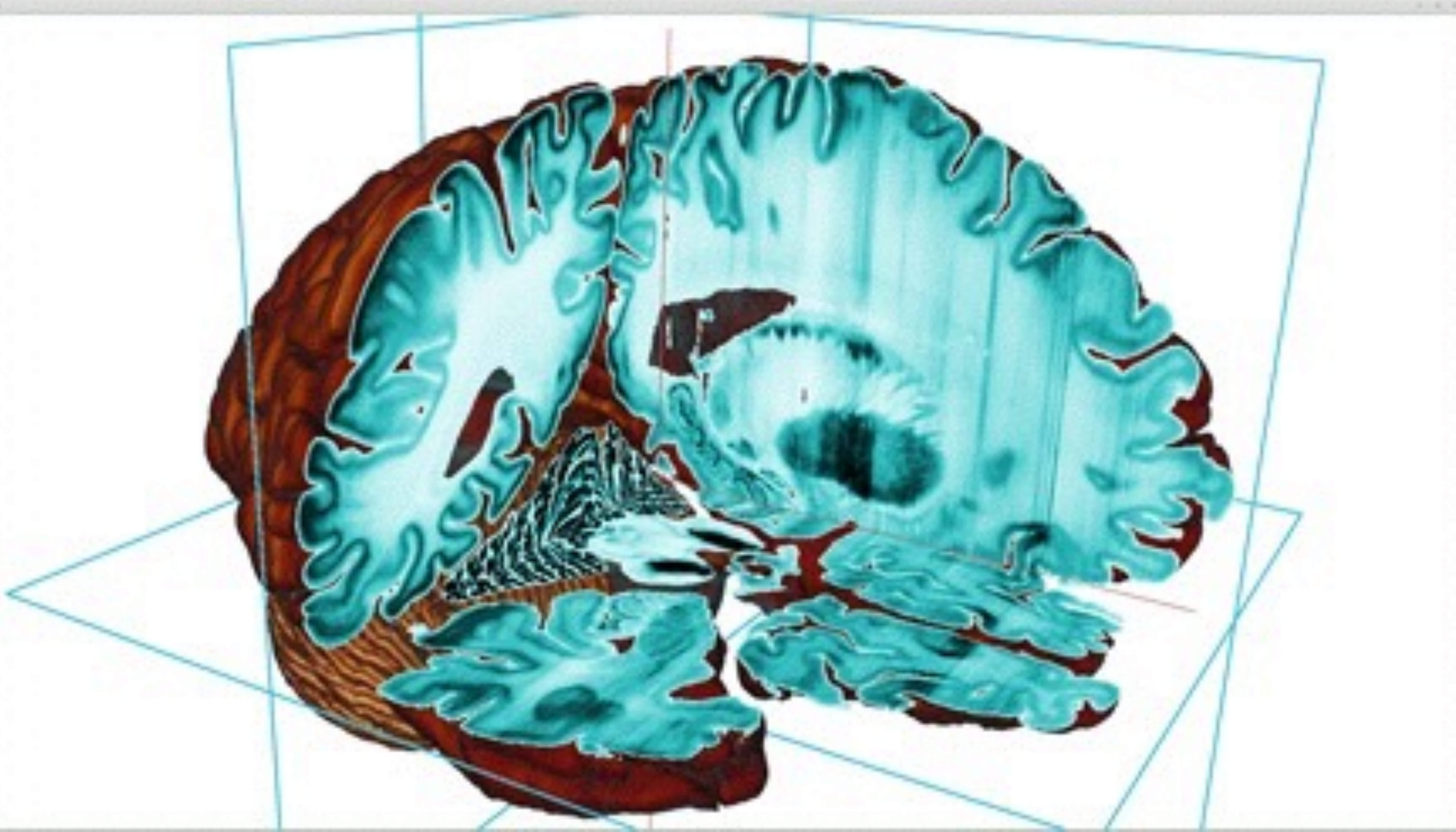
Knowledge evolves with the knower: $K=K(t, s)$, where t is time and s the knowing subject. The collection of neural processes of s changes with time. Knowledge, being a collection of physical processes and not a set, is *physical*, not conceptual. Hence, *knowledge can be destroyed*: it is enough to destroy the brain of s to terminate with the associated cognitive processes.

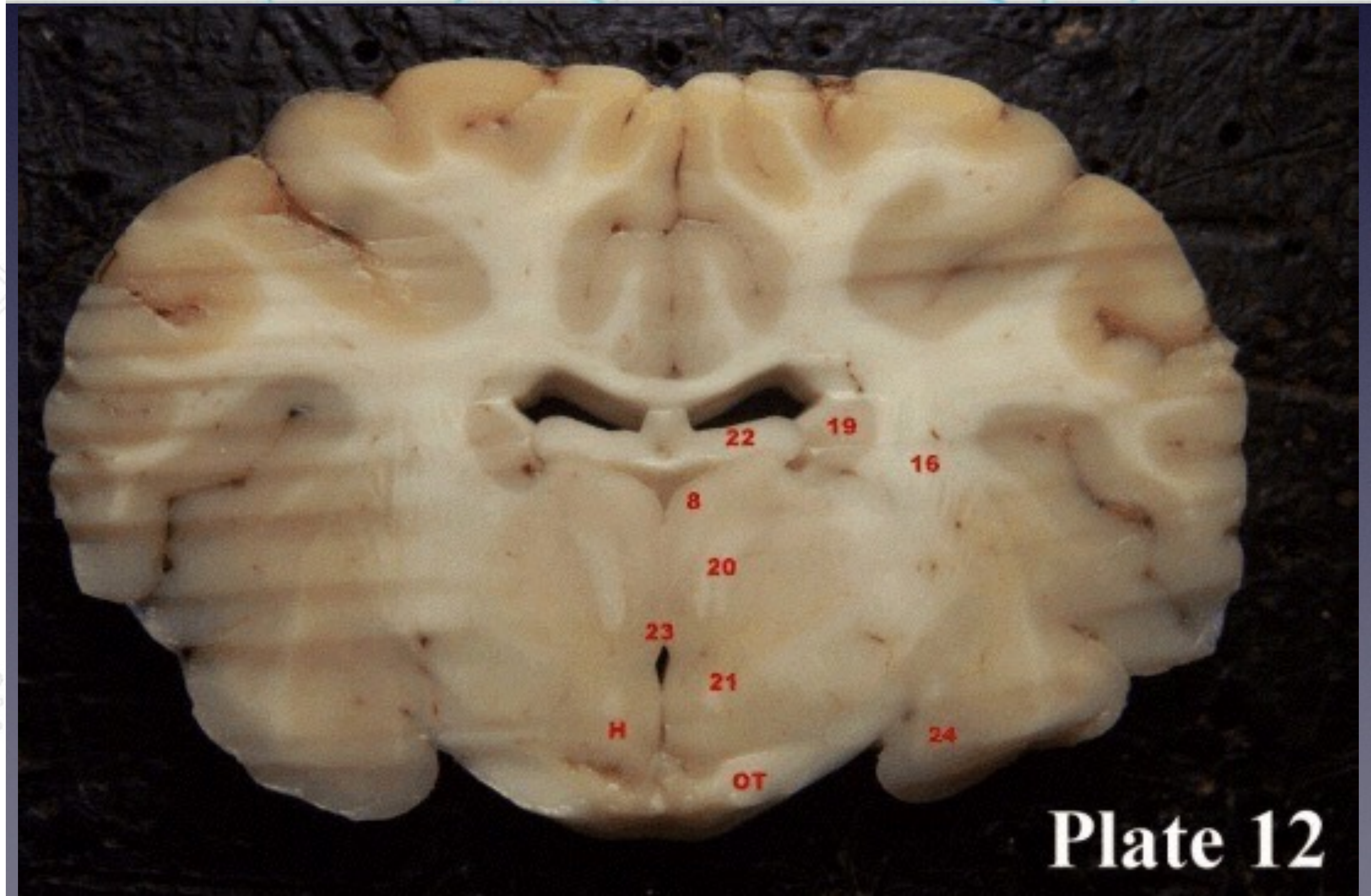
As a corollary, notice that there is no knowledge in a library or in the internet; knowledge is only in the brains of the readers. When they interact with the books or the screen of a computer, they experience cognitive processes, that resemble those of the authors of the texts.

Books and articles do not have knowledge. They are instruments designed to create knowledge.

The brain acts as a dense network of fiber pathways consisting of approximately 100 billion (10^{10}) neurons. The brain consists of three main parts – stem, cerebellum and cerebrum - . Of the three, the cerebrum is most important in learning, since this is where higher-ordered functions like memory and reasoning occur. Each area of the cerebrum specialises in at least a function - sight, hearing, speech, touch, short-term memory, long-term memory, language and reasoning abilities are the most important for learning.


Frontal Lobe
Problem solving
Emotional traits
Reasoning (judgment)
Speaking
Voluntary motor activity
Parietal Lobe
Knowing right from left
Sensation
Reading
Body orientation
Occipital Lobe
Vision
Color perception
Temporal Lobe
Understanding language
Behavior
Memory
Hearing
Cerebellum
Balance
Coordination and control of voluntary movement
Fine muscle control
Brain Stem
Breathing
Body temperature
Digestion
Alertness/sleep
Swallowing

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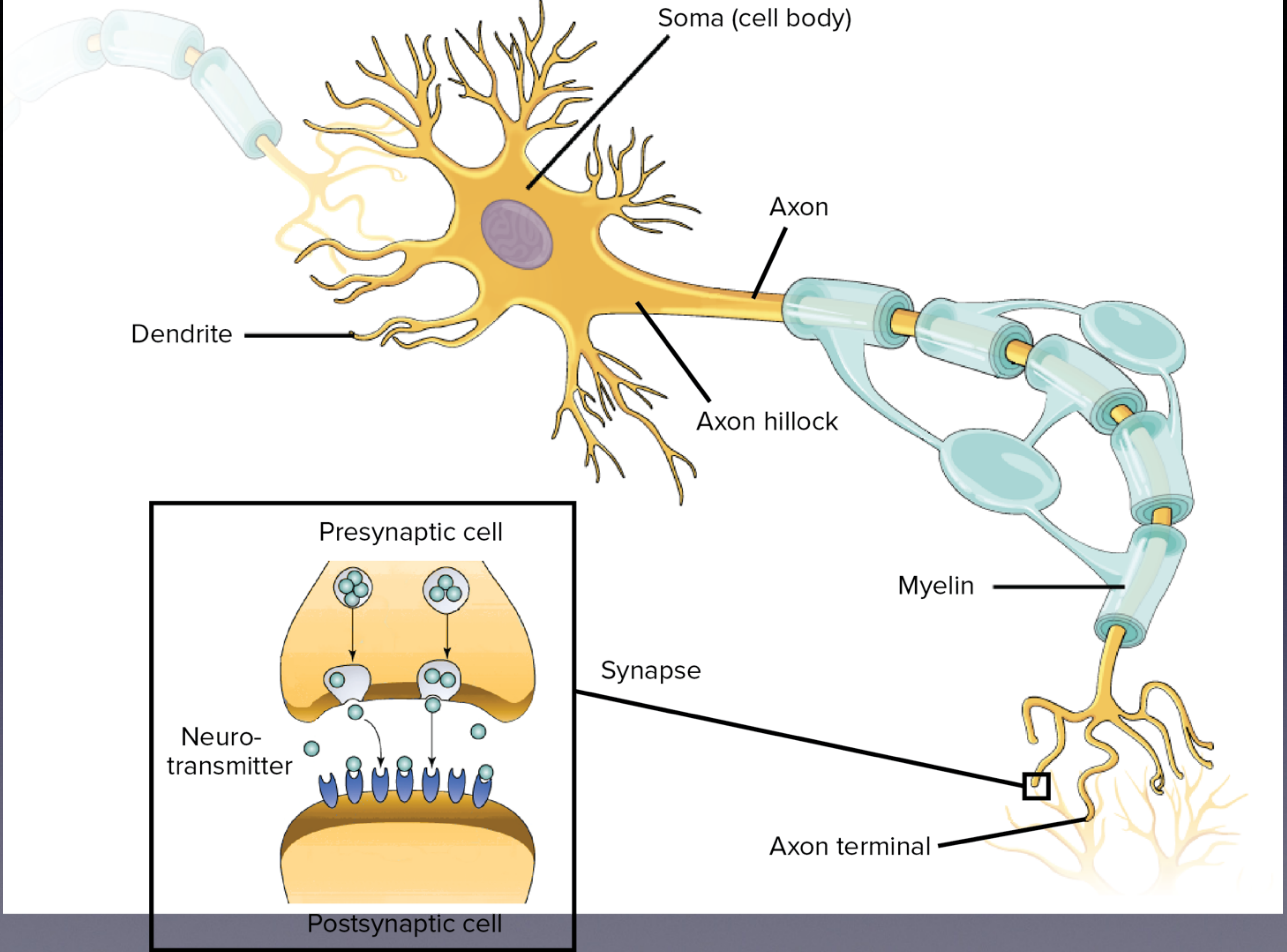
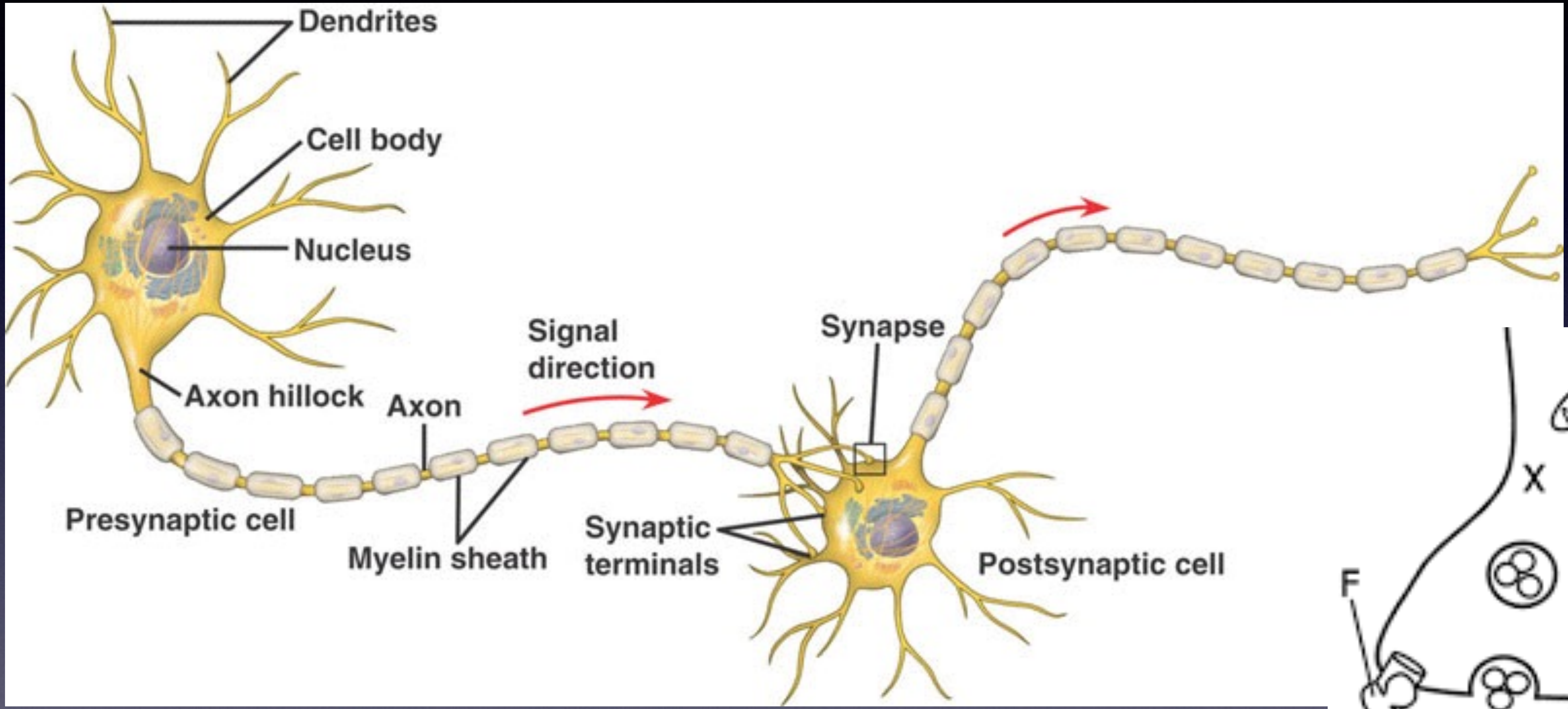
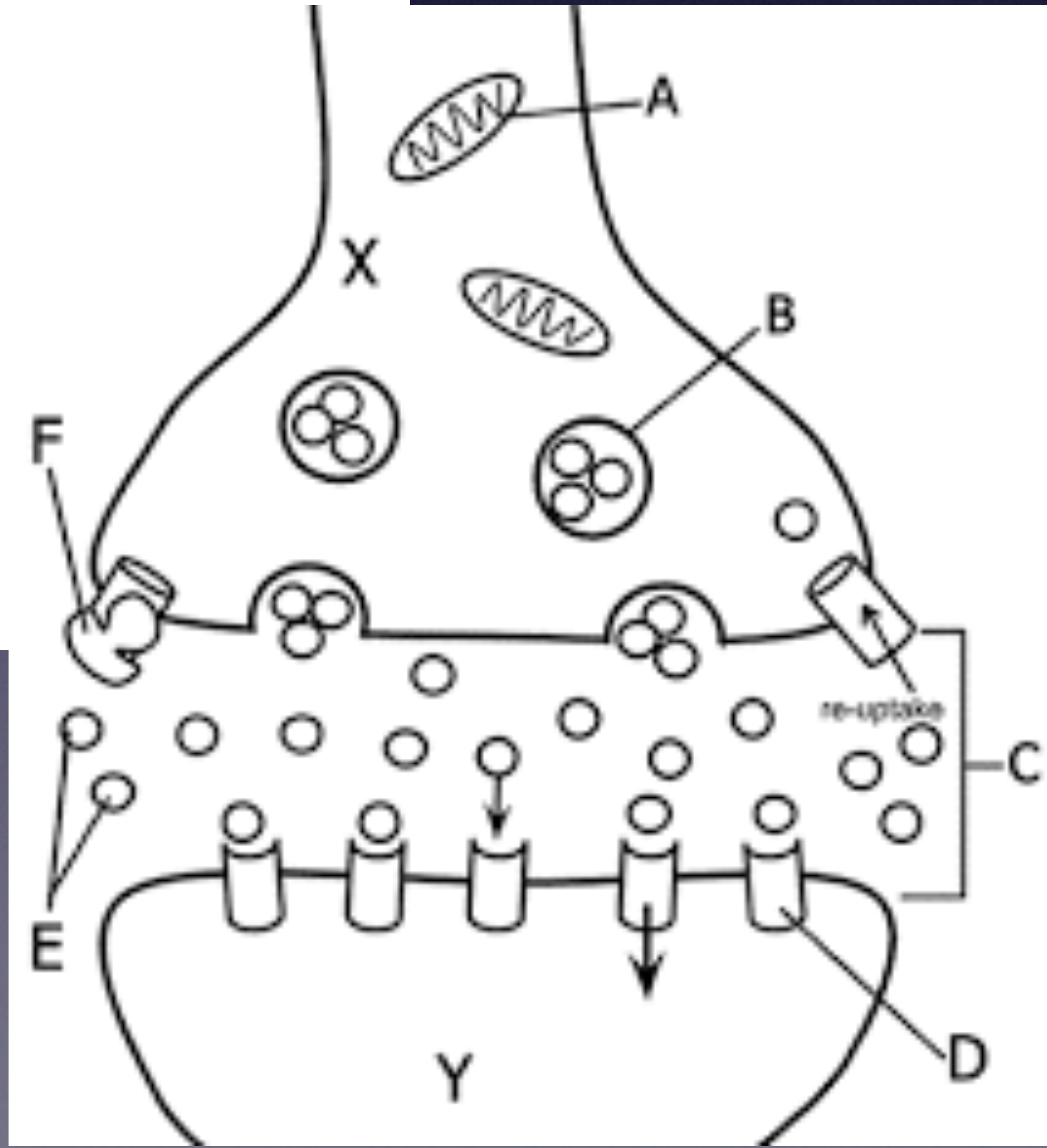
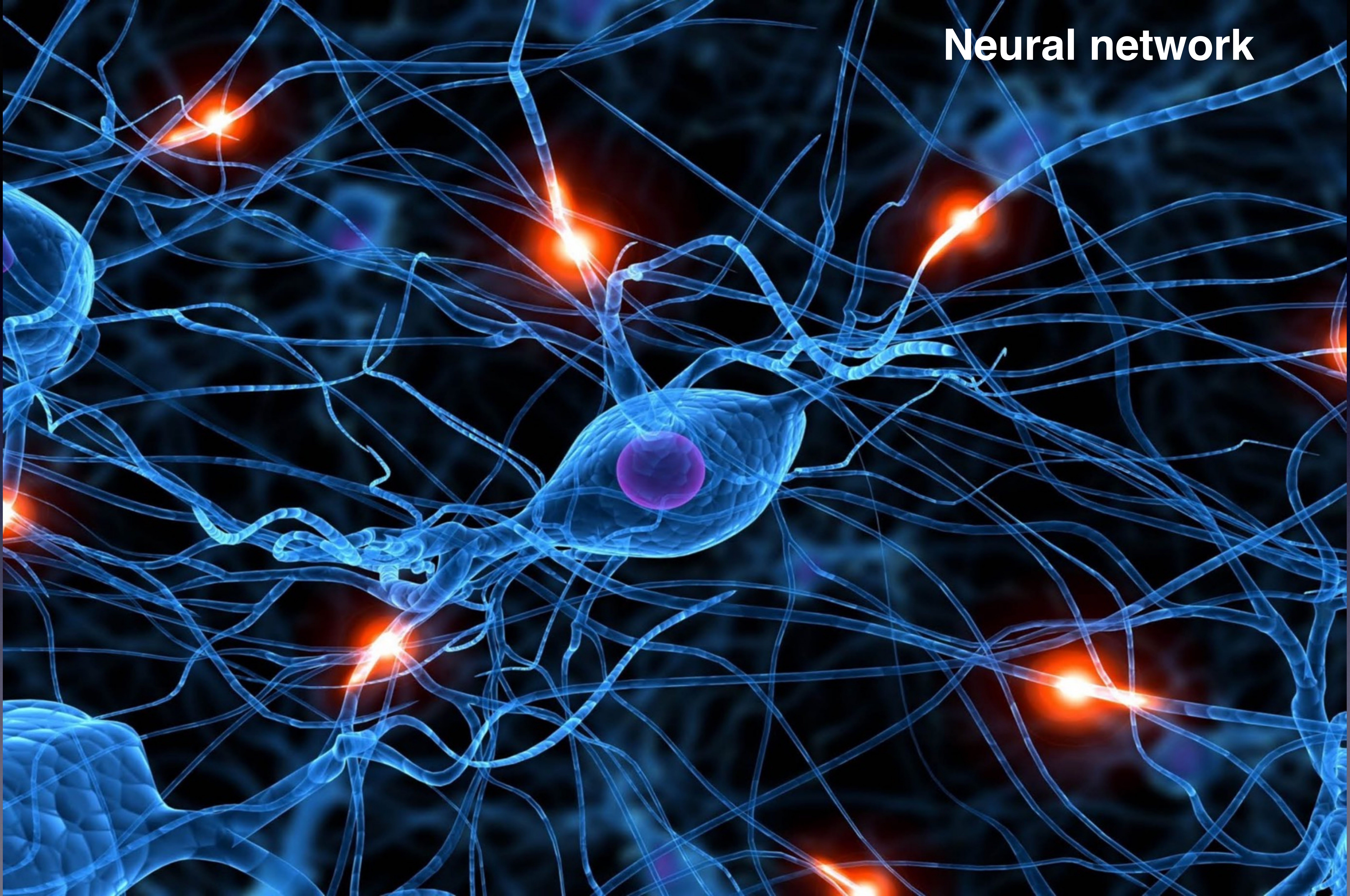

Soma (cell body)
Axon
Dendrite
Axon hillock
Presynaptic cell
Myelin
Synapse
Neuro-
transmitter
Axon terminal
Postsynaptic cell

Neural connections






Neural network

Some recent brain research findings

* Frequency and recency of neuron synapses increase memory
* Emotions strengthen memory
* Learning causes changes to the physical structure of the brain
* Memories are stored in multiple parts of the brain
* Our brains are programmed to focus on new and unusual inputs

Neuroplaticity

Understanding

Understanding is a *congitive operation* that applies to facts, symbols, and constructs. It consists in fitting an item into the pre-existing cognitive or epistemic network of knowledge, or in transforming this network to accommodate the new item into a consistent way.

It is a complex operation that proceeds in various ways. The main ways of understanding are ***description***, ***subsumption***, and ***explanation***.

Description

A ***description*** is a characterisation of a fact or a concept. From a logical point of view a description is *an ordered set of statements*. Mathematical descriptions can be complete, but never factual ones. A description can reveal some features of a fact, but since none description is exhaustive, *we never fully understand from description.*

Subsumption

Subsumption is also *an ordered set of statements*, but one in which the last statement follows from the preceding ones. A singular fact can be subsumed under a general pattern:

$$\forall x\ Px \vdash Pa$$

$$\forall x\ (Px \rightarrow Gx) \land Pa \vdash Ga$$

Subsumption

Sometimes, the pattern occurring in a subsumption is merely a classificatory statement and not a law statement. In such a case:

1. $S = \{x : Px\}$
2. $a \in S$
3. Then, $P(a)$

Explanation

Explanation, as subsumption, is a case of deduction from regularities and circumstances, in particular law statements and data. Explanation, however, answers "why"-type of questions through the use of mechanisms. The logical form of explanation is:

$$\forall x \, [(Fx \rightarrow Mx) \wedge (Mx \rightarrow Gx) \wedge Fa] \vdash \; Ga$$

M stands for ***mechanism***.

A ***mechanism*** is a collection of processes in a material system that allow the system to perform some ***functions***.

A ***function*** is some specific activity of a system.

Accordingly, <u>to explain is to exhibit or conjecture a lawful mechanism that makes the system to work the way it does</u>.

Mechanisms, and hence explanations, can be classified in accordance with the underlying class of process: ***causal***, ***random***, or ***mixed***. All mechanisms are lawful, but the law-mechanism relation is one-to-many, not one-to-one: the same activity can result from different mechanisms.

Mechanisms are <u>*not*</u> universal like laws, because mechanisms are system-specific.

Explanation subsumes subsumption, logically, epistemologically, and ontologically.

Logically because given an explanation we can detach the corresponding subsumption:

$$\forall x\,[(Fx \rightarrow Mx) \wedge (Mx \rightarrow Gx)] \vdash (Fx \rightarrow Gx)$$

Epistemologically because explanation requires more knowledge than subsumption.

Ontologically because explanation goes deeper into the structure of reality than subsumption.

An explanation is an epistemic process involving three components: 1. ***An explainer*** (e.g. a human being), 2. ***The object of the explanation*** (e.g. luminosity of a star), 3. ***The explanatory premises*** (e.g. nuclear fusion reactions occur at such and such pressures, radiation is transported in the stellar interior according to such and such processes, etc).

The objects of explanation can be things, properties or states of things, or events.

Not everything can be explained and not everything explainable is worth to be explained. The value of explanation will depend on our axiology.

Some methodological rules to explain

- E1. Check the existence of the item to be explained (fact, thing, event).
- E2. Try to explain existents by existents, and only exceptionally by conjectural entities (never by fictions).
- E3. Explain the observable by the non-observable or the unobservable by the observed.
- E4. Avoid ad-hoc explanations, i.e. those which require hypotheses that cover only the item to be explained.
- E5. Mistrust hypotheses and theories that purport to explain everything.

Model

A ***factual model*** is the conceptual representation of a mechanism.

$$M = \langle D, F, I, A \rangle$$

- *D* is a *domain* or reference class of *M*. It is a set of factual items: things or processes.
- *F* is the *formalism* of *M*, i.e. the set formed by the mathematical expressions used to represent elements of *D*.
- *I* is the *interpretation* of *M*. The interpretation is a set of partial functions from *F* to the power set of *D*, that assigns formulas in *F* to factual items in *D*.
- *A* is a set of specific *assumptions* and *data*.

Important: a model is *not* an application of mathematics to reality: it is a mathematisation of our ideas about reality.

Occasionally we know sufficient mathematics as to build alternative but empirically equivalent models of a given process or mechanism. Every model is symbolic and as such has some conventional elements.

Since mathematisation involves idealisation, models are always defective in some aspect or another. At best, they are good approximations but *they should not be confused with reality*.

Theories

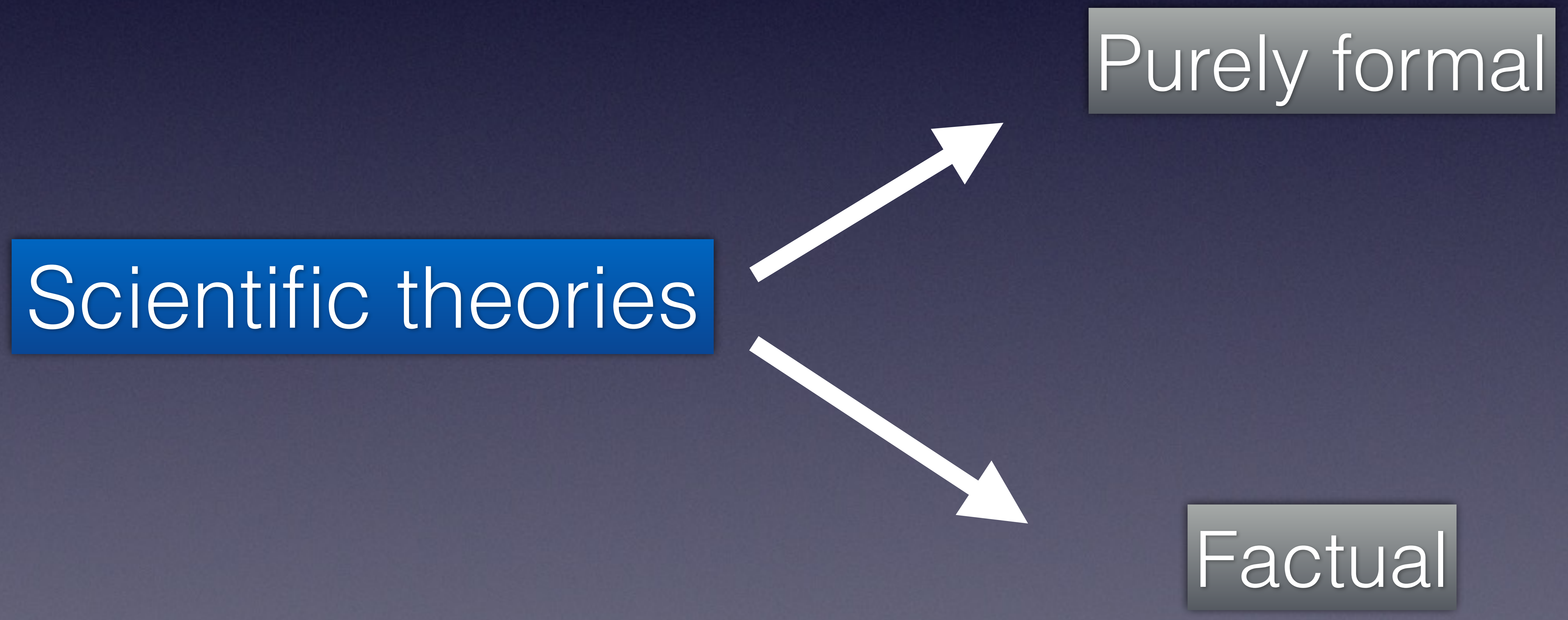
A ***theory*** is a logically organised set of statements concerning objects of some kind. If we introduce a set of statements P, a set of predicates Q, and a domain (reference class) R, a theory is defined by the quadruple:

$$T = \langle\, P,\ Q,\ R,\ \vdash \,\rangle$$

A theory then is a context closed under deduction: every statement in it is either a premise or a deductive consequence of a set of premises. The premises are called ***axioms***, and the consequences ***theorems***.

Theories

If *R* is a set of conceptual objects only, then the theory is purely ***formal***. If the reference class include some factual item (material system) the theory is ***factual***.



Theories

Axioms

Formal: mathematical or logical relations between primitive terms

Semantic: fix the reference class and the representation relations between functions and properties.

Nomological: law statements

Theories

The presentation of a theory has other components: a generating basis of primitive concepts, a background of assumed theories, a language and a metalanguage, definitions, and an infinite number of theorems.

Notice that to the contrary of models, theories contain law statements.

Sub-theories are parts of a theory that are theories in themselves. For instance, the theory of gravitational waves is a part of general relativity.

Theories and models

In general, we obtain models through a number of theories (T_1, T_2, …, T_n) and sets of specific assumptions (A_1, A_2, … , A_m):

$$(T_1 \wedge T_2 \wedge ... \wedge T_n) \cup (A_1 \wedge A_2 \wedge ... \wedge A_m) \vdash M.$$

When we go from general theories to models the reference class shrinks.

General theories, contrary to models, are not expected to make predictions unless considerably enriched with special assumptions and data.

Validation

We put theories to the test through ***consistency analysis*** (both internal and with the total network of theories) and by ***empirical evaluation of models*** obtained from the theories with specific assumptions and data on applications to specific cases.

Data

Theories are tested through the comparison of model predictions (statements) with data. *An empirical datum is not a fact but a proposition reporting a fact.* We always compare propositions with propositions. Since propositions are conceptual objects, they are *theory-laden*. The fact themselves, of course, are theory-independent.

An ***empirical datum*** is a simple proposition referring to a factual state acquired with the help of empirical operations.

Evidence

An empirical datum *e* constitutes empirical evidence for or against a proposition *p* iff:

1. *e* has been acquired with the help of empirical operations accesible to public scrutiny.
2. *e* and *p* share referents.
3. *e* has been interpreted in some theoretical framework.
4. Some regular association between the properties represented by predicates in *e* and *p* is assumed.

The mentioned empirical operations involve several theories and data manipulation to evaluate errors.

Science

Science is the result of a systematic human activity which aims at acquiring true knowledge about the world. It is a ***complex activity*** and hence difficult to characterise. It is not the only way of getting human knowledge. Science differentiate from other knowledge acquiring operations in that ***it is systematic*** and its results are ***subjected to a variety of controls***. In addition, ***it is a progressive activity*** in the sense that scientific knowledge increases with research. There are several ***indicators of scientific progress*** including improvement of predictability and augmentation of human capability to manipulate the environment (science-based technology).

Science produce conceptual representations of the world, articulated in theories and models.

Science

Science can be defined as a set of fields of research. Each field of research *R* is characterised by the following items:

C: A community of researchers.
S: A society that hosts the activities of those individuals in C
D: A domain of items to be researched and studied.
G: A general philosophy shared by the members of C.
F: A set of formal languages used by the researchers.
B: A background of previous scientific knowledge.
P: A collection of problems.
A: A collection of goals of the members of C respecto to D.
M: A specific methodology that is used to answer the problems in P.
E: An ethics common to the members of C.

Science

Then, the research field R is represented by:

$$R=<C, S, D, G, F, B, P, A, M, E>$$

The elements of each component change with time, hence these components are collections and not sets. The research field evolves according the evolution of its components.

Science, then, can de defined as the set of all research fields:

$$Sci=\{R_1, R_2, \dots, R_n\}$$

Notice that science is *not* equivalent to scientific knowledge. The latter is total knowledge of the members of C. These knowledge can be learned by different individuals by different ways.

Since science has no brain, it cannot be responsible for the actions of members of C or the application of scientific knowledge. Only human beings can be responsible for the actions they do.

Technology

Technology is related to our capacity to manipulate our environment. Not necessarily all technology is based on science. Technology is older than science. Science-based technology can be characterised as a human activity that aims at designing, developing, constructing, and controlling ***artifacts*** using knowledge obtained through science.

An artifact is an artificial thing that can be controlled and used to specific goals. Artifacts are not only mechanic. They can be electronic, thermodynamic, biologic, or cultural.

Technology also deals with the planning of human actions with the aim of controlling various processes, always on the basis of scientific knowledge.

Technology

C_i: Community of technologists.
S: A society that host C_i.
D_i: Set of things that T_i deals with.
F_i: Set of formal theories used by the members of C_i.
E_i: Set of scientific theories and data used by the members of C_i.
P_i: Specific problematic.
A: Total technological knowledge available to the members of C_i.
O_i: Set of final goals of the members of C_i.
M_i: Methodological rules and instructions used by the members of C_i.
V: Value system adopted by the members of C_i.

Notice that scientific technology includes not only the many engineerings but also medics, didactic, normative epidemiology, regulative economy, law, and all disciplines of social planning.

Technology

The concept of a specific scientific technology can be defined as:

$$T_i = \langle C_i, S, D_i, F_i, E_i, P_i, A, O_i, M_i, V \rangle$$

So, the technology of a given society is the collection of all specific scientific technologies:

$$T = \{T_1, T_2, \ldots, T_n\}$$

Pseudo-science and pseudo-technology

Science and technology can be faked: there are activities and artifacts presented or offered as scientific or technological which actually are not. Being modern science and technology quite complex, it is not a simple task to identify impostures.

In general, a simple demarcation criterion fails because a simple rule cannot take into account the complexity and systemic character of science and technology. A case by case study is necessary.

Pseudo-science and pseudo-technology

It is also important to differentiate pseudo-science from proto-science, i.e. science in the making.

Examples of proto-sciences are most of the social sciences, whereas notorious pseudo-sciences are astrology, psychoanalysis, parapsychology, ufology, and dialectics. Among pseudo-technologies we can mention neoliberal economy, homeopathy, psychoanalytic therapies, and the many health impostures related with the New Age movement.

Science	Pseudoscience
Willingness to change with new evidence	Fixed ideas
Ruthless peer review	No peer review
Takes account of all new discoveries	Selects only favourable discoveries
Invites criticism	Sees criticism as conspiracy
Verifiable results	Non-repeatable results
Limits claims of usefulness	Claims of widespread usefulness
Accurate measurement	“Ball-park” measurement

7 Ways to Identify Pseudoscience

1. The use of psychobabble – words that sound scientific and professional but are used incorrectly, or in a misleading manner.

2. A substantial reliance on anecdotal evidence.

3. Extraordinary claims in the absence of extraordinary evidence.

4. Claims which cannot be proven false.

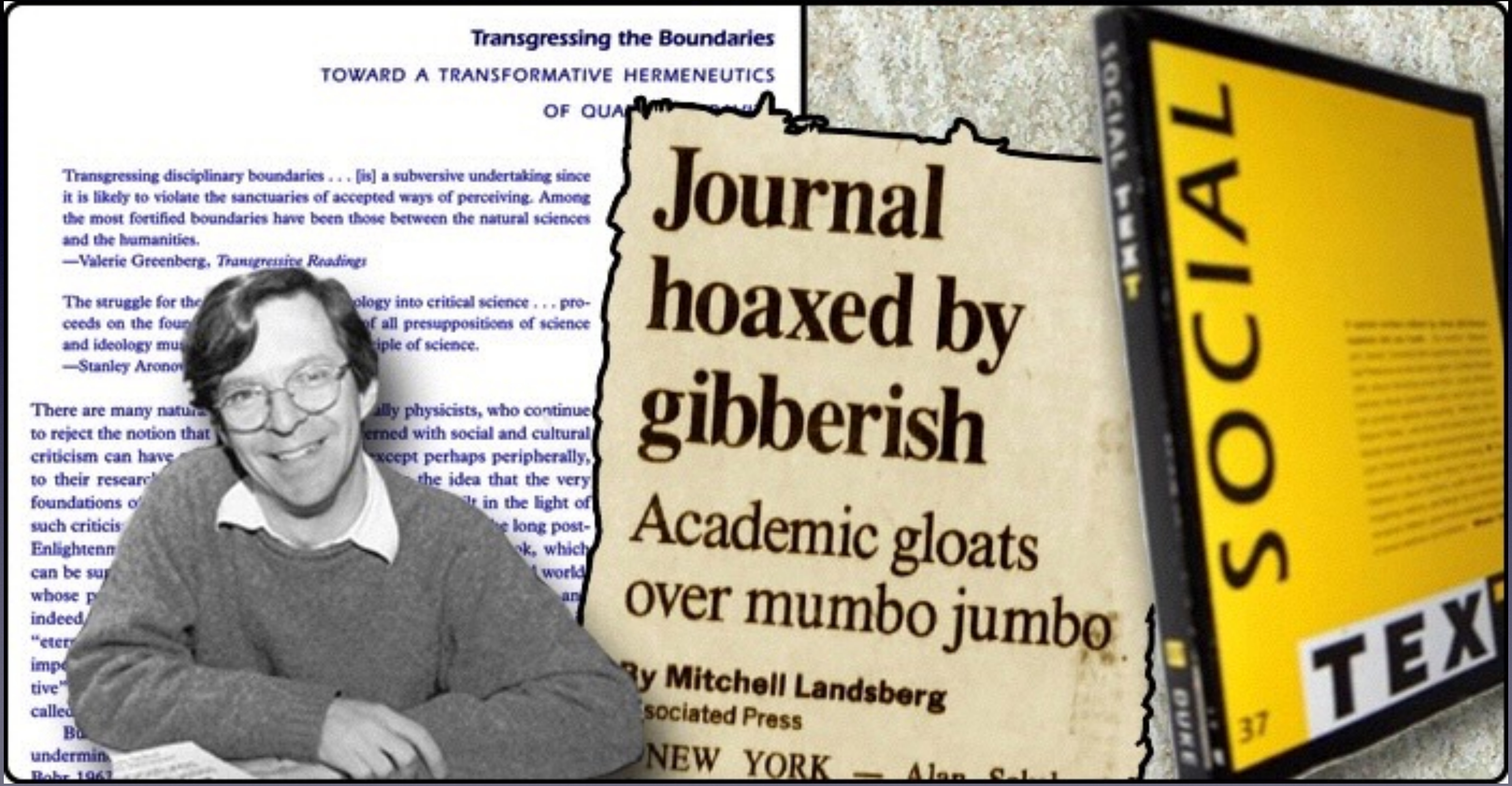
5. Claims that counter established scientific fact.

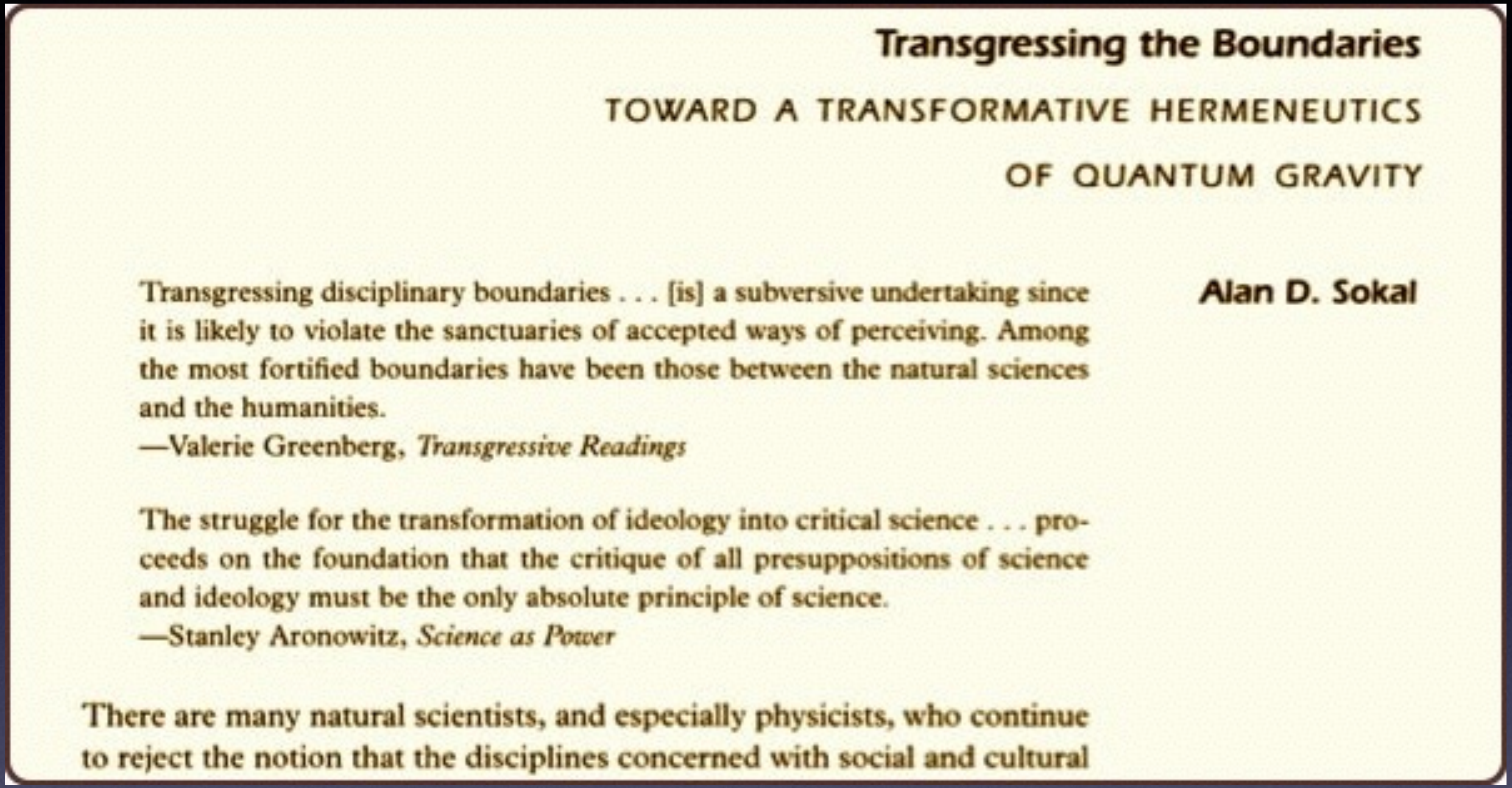
6. Absence of adequate peer review.

7. Claims that are repeated despite being refuted.

Source: Frontiers in Psychology, Hauntings, homeopathy, and the Hopkinsville Goblins: using pseudoscience to teach scientific thinking by Rodney Schmaltz and Scott O. Lilienfeld
http://journal.frontiersin.org/Journal/10.3389/fpsyg.2014.00336/abstract

Academic nonsense





Transgressing the Boundaries

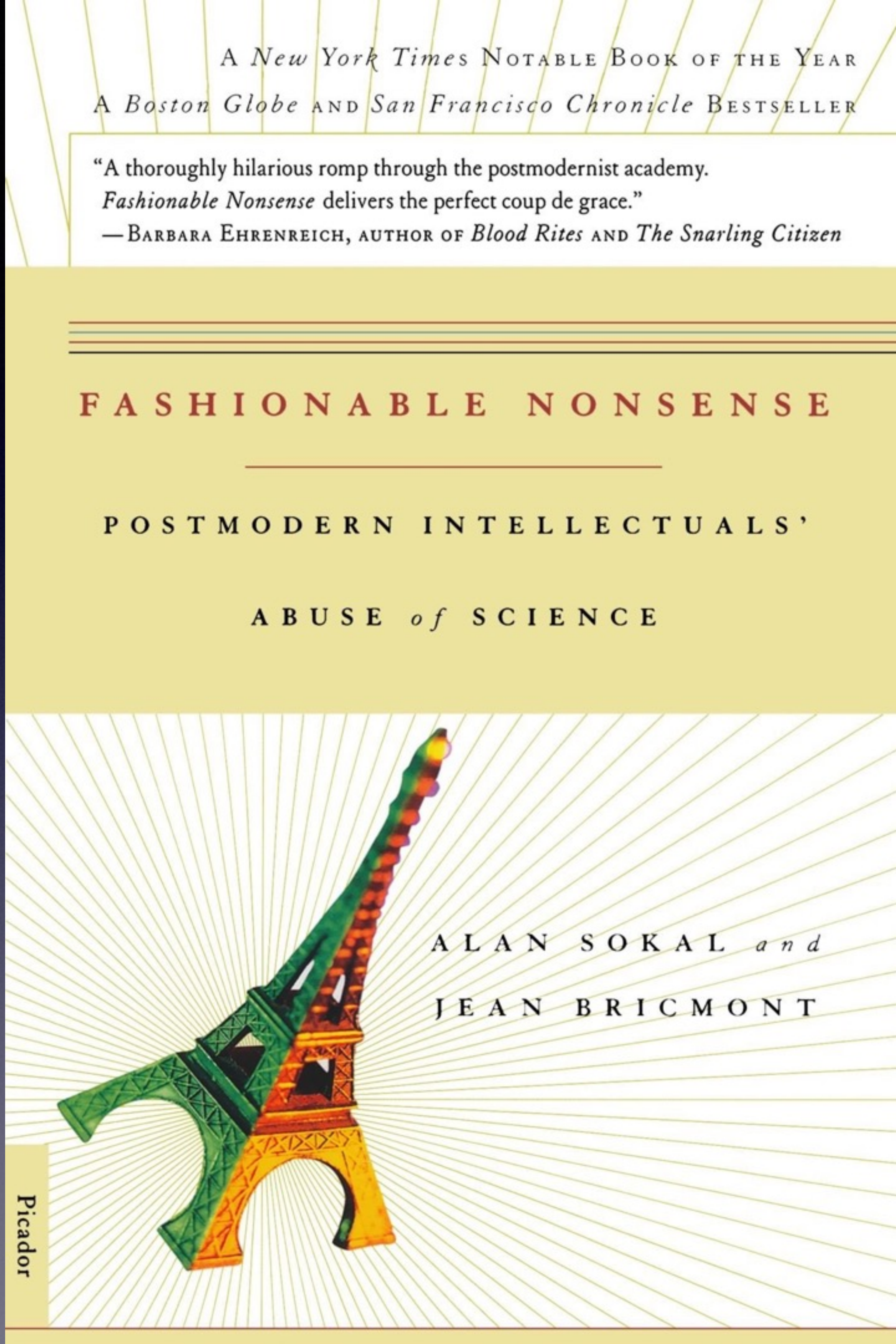
TOWARD A TRANSFORMATIVE HERMENEUTICS OF QUANTUM GRAVITY

Alan D. Sokal

> Transgressing disciplinary boundaries . . . [is] a subversive undertaking since it is likely to violate the sanctuaries of accepted ways of perceiving. Among the most fortified boundaries have been those between the natural sciences and the humanities.
> —Valerie Greenberg, *Transgressive Readings*

> The struggle for the transformation of ideology into critical science . . . proceeds on the foundation that the critique of all presuppositions of science and ideology must be the only absolute principle of science.
> —Stanley Aronowitz, *Science as Power*

There are many natural scientists, and especially physicists, who continue to reject the notion that the disciplines concerned with social and cultural

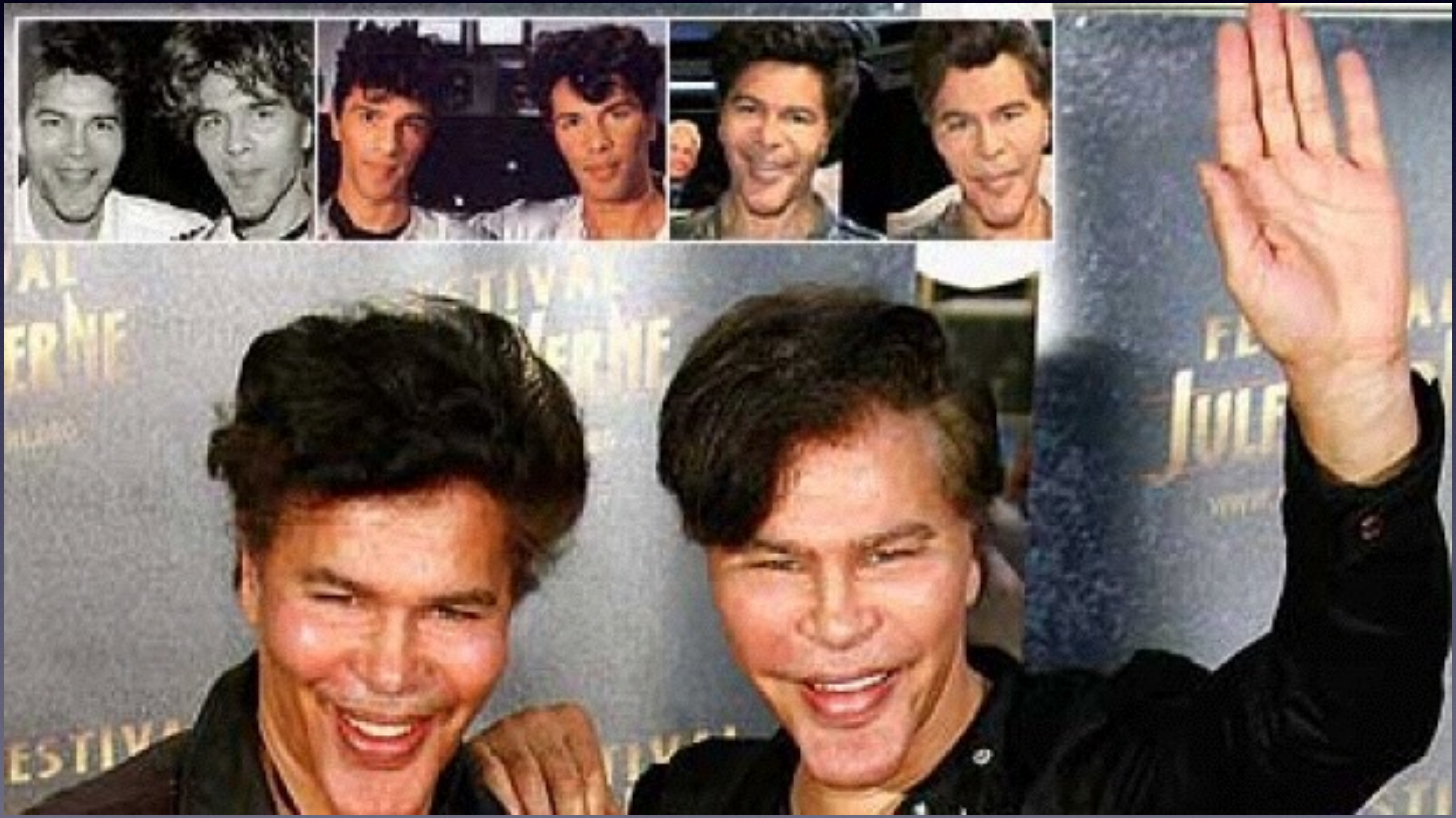


The Bogdanov affair

The Bogdanov Affair is an open debate on the value of a series of articles on theoretical physics written by French twin brothers Igor and Grichka Bogdanov. On the basis of these articles the brothers obtained two doctorates in France.

The affair demonstrated the permeability of scientific publishing system to meaningless jargon. And showed how the pursuit of fame can be a mobile to simulate a scientific career.

Bogdanov affair



Peter Woit: "The work of the Bogdanoffs is significantly more incoherent than anything else published. But the growing low level of consistency throughout the field allowed them to think they had done something sensible and publish.."

Jacques Distler: “The articles of Bogdanoffs consist of technical jargon from several fields of mathematical physics, string theory, and quantum gravity. It is a set of syntactically correct sentences but semantically meaningless, arranged as to look as a scientific article.”

Anti-science: Gurus, media stars, and prophets instead of scientists. Hawking's case.

"I think computer viruses should count as life. I think it says something about human nature that the only form of life we have created so far is purely destructive. We've created life in our own image."

Stephen Hawking

Some desirable virtues in a scientists

1. Intelectual honesty
2. Independence in judgment
3. Intelectual courage
4. Respect for freedom of thought
5. A sense of justice

Letter on the rights and duties of the Professor (Mario Bunge)

1. Every Professor has the right to search for thruth and the duty to teach it.

2. Every Professor has the right and duty to question everything, as far as she does it rationally.

3. Every Professor has the right to make mistakes and the duty to correct them if she becomes aware of them.

4. Every Professor has the duty to denounce charlatanism, both popular or academic

….

Summing up: ***Knowledge*** is the result of the process of ***learning*** by some biological system. It is not related to ***belief*** and it is not necessarily true. Actually, not all knowledge is propositional: there is motor-sensitive knowledge and perceptual knowledge, in addition to conceptual. ***Understanding*** is a cognitive operation that consists in the accommodation of ***data*** about the world into our conceptual view. There are three ways of understanding: ***description***, ***subsumption***, and ***explanation***. The latter is the deeper one, and consists in exposing the ***mechanism*** that produce the activity to be explained. The conceptual representation of a mechanism is a ***model***. ***Theories*** are hypothetical-deductive systems of propositions close under deduction that include ***law statements***. With the help of specific conditions, theories are used to construct models, and these used to validate theories. Our network of theories is the result of ***science***, a complex human activity designed to systematically increase our knowledge. ***Technology*** based on science allows to manipulate and control our environment and create artefacts.