

What is Bioinformation?

Nishinomiya-Yukawa Internat. & Interdisc. Symposium on “
What is Life? The Next 100 Years of Yukawa's Dream”

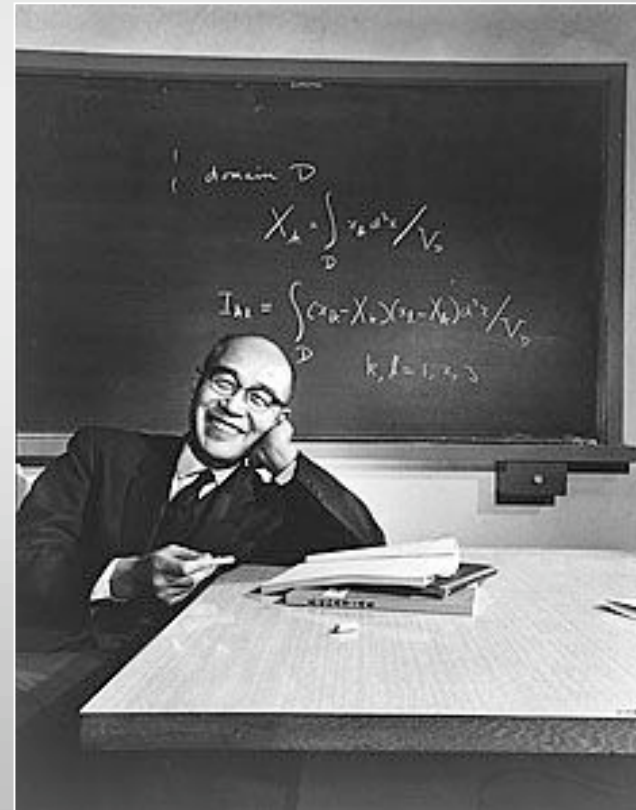
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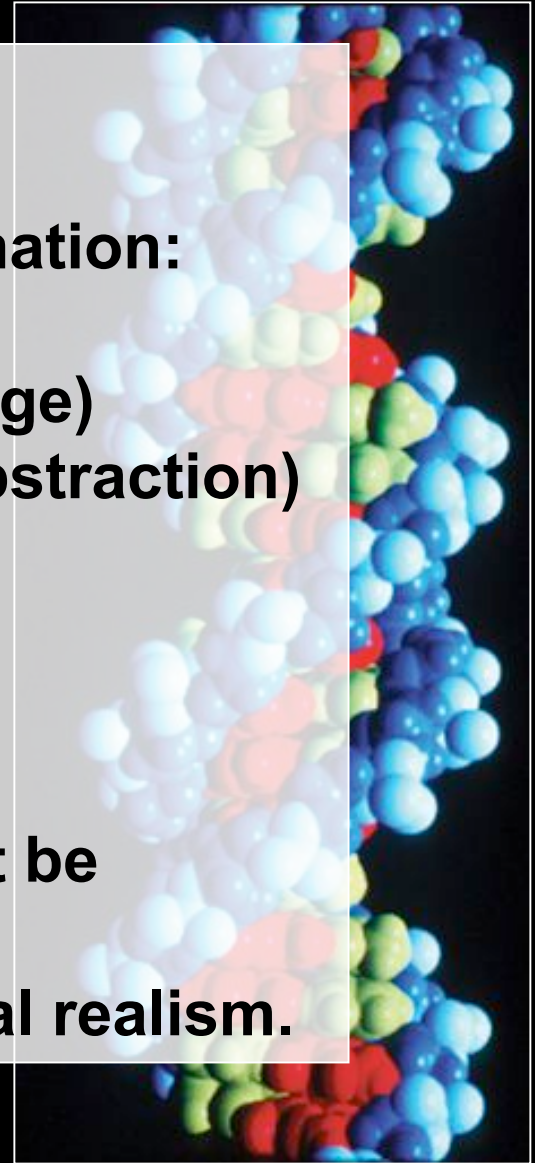
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Summary

- 1. A vexed issue: what is information?**
- 2. Four problems with biological information:**
 - a. biology vs. genetics (theory)**
 - b. attributive vs. predicative (language)**
 - c. syntactic vs. semantic (level of abstraction)**
 - d. ordinary vs. exceptional (ethics)**
- 3. A possible solution:**
 - a. what biological information is not**
 - b. what biological information might be**

Conclusion: bio-informational structural realism.



1. What is Information?

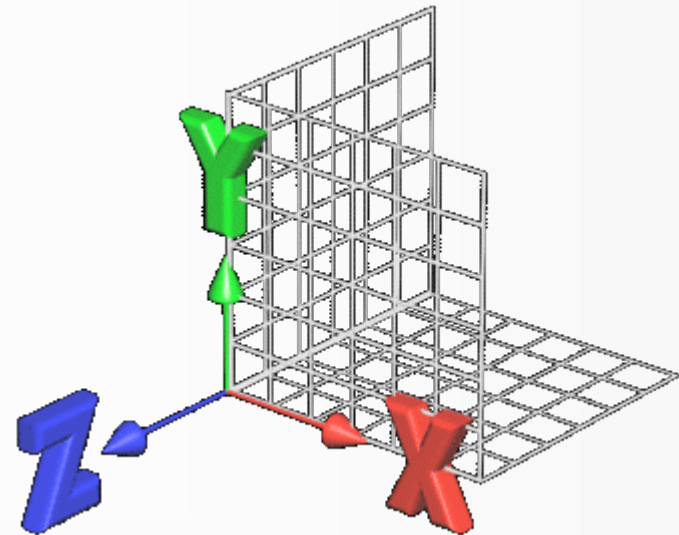
The three main dimensions of information are:

- information as reality, e.g. patterns, fingerprints, tree rings (x)
- information for reality, e.g. a command, an algorithm, a recipe (z)
- information about reality, i.e. with an epistemic value (y)

We shall concentrate our attention on (x):
biological information as reality.

Examples of bio-information as reality:

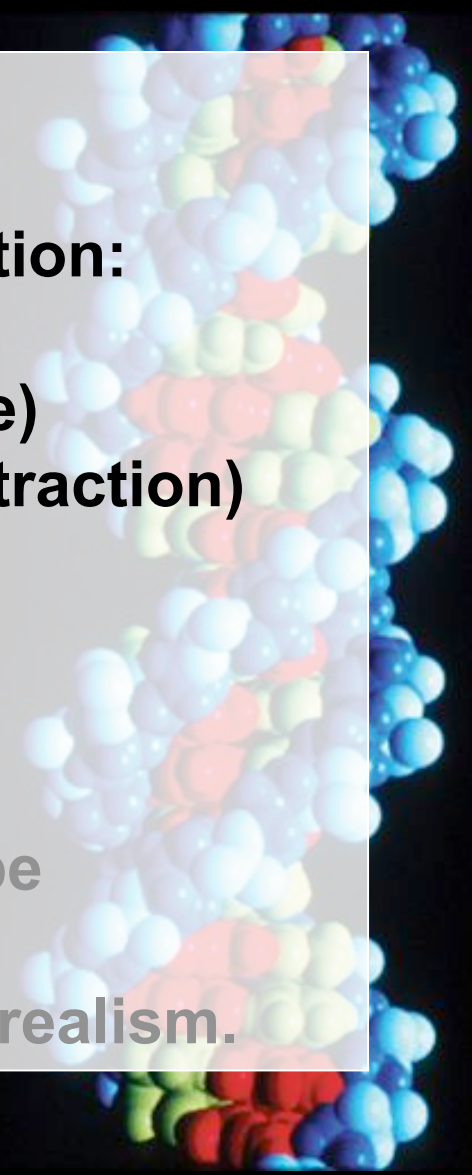
- genes are bearers of information
- genes contain programs
- genes are informational instructions
for the development and functioning of organisms



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2.a Biology vs. Genetics

Biological information is used in at least three main contexts:

- a) animal communication (ethology) We are interested in information to each other about food source biological information movement gives rise to sound impulses that understood as genetic hairs on the back of the bee's head; the orientation of the bee also has significance. Cf. also ants etc.
- b) neuroscience, e.g. computational models of various neuronal systems involved in learning and memory processes etc.
- c) genetics: reproduction and evolution (molecular biology).

Three issues:

- can information be reduced to communication?
No.
- is there no information in a lifeless universe (with or without human artefacts)?
No. Example: food and nitrobacteria (unicellular organisms).
- can there can be a unified theory of biological information that captures (a)-(c) satisfactorily?
No (at least without being too generic).

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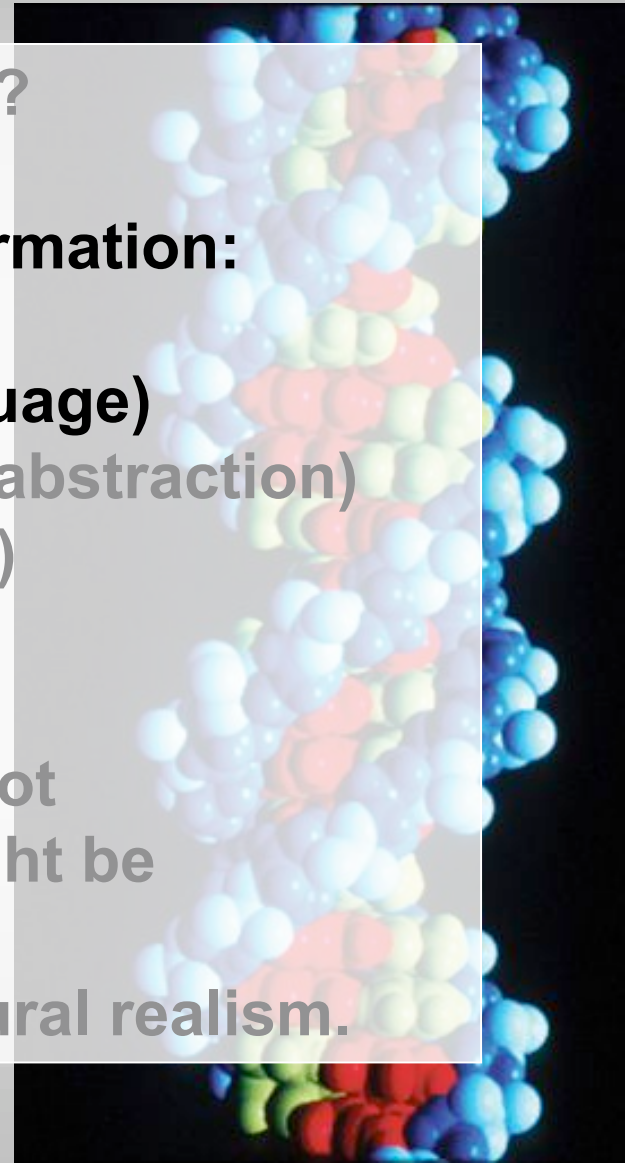
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2.b Attributive vs. Predicative

Speaking of biological information can be confusing
For example, in a recent article one can read:

Information about

Information about/as something

Should insurers have a right to, or a right to seek, genetic information about potential policy holders? Should employers be allowed to require a job applicant to provide a DNA sample that would then be used to test for various 'predispositions' to certain traits? Do the offspring of sperm donors have a right

Information about

to acquire genetic information about their 'natural' fathers? Can genetic information be patented? Is it ever justifiable to override patient confidentiality in

Information as something

order to disclose useful, relevant but perhaps disturbing genetic information to family members who may be, unwittingly, at risk of developing some debilitating condition in later life? What constraints should there be on the storage and dissemination of personal genetic information?

Information as something

N. C. Manson "What is Genetic Information, and why is it Significant? A Contextual, Contrastive, Approach" *Journal of Applied Philosophy*, Vol. 23, No. 1, 2006

Information as something

2.b Attributive vs. Predicative

It is important to distinguish between what one is interested in.

The distinction is not merely linguistic, but can more easily be explained linguistically in terms of two different uses of “biological”:

A) Attributive biological information is information about biological facts.

P) Predicative biological information is information whose nature is biological in itself.

A) Common in bioinformatics.

Nobody disagrees about the existence of biological information.

A mix of synt. and sem. theory of information perfectly fine.

P) Debate on whether any biological facts count as informational and if so,

What sort of informational stuff they are; and

What kind of information theory is needed to capture their nature.

It is controversial whether biological processes and elements are intrinsically informational rather than interpretable informationally.

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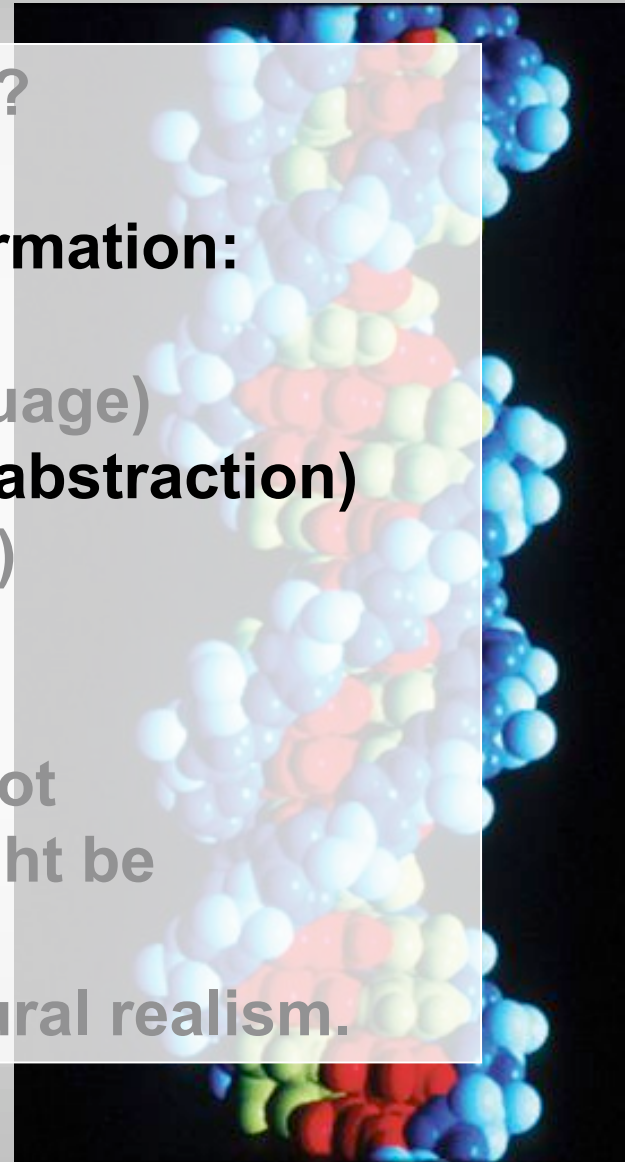
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2.c Syntactic vs. Semantic

We are interested in the predicative sense of biological information.

There are many theories of information.

The three most commonly used theories of information are:

M) Mathematical theory of communication (Shannon)

This is syntactic, based on probability theory (number of alternatives) and works on signals transmission, processing and storage independently of their content. It does not concern truth, meaning, relevance or significance of the signals.

S) Semantic theory (e.g. Bar-Hillel and Carnap, Dretske, Floridi).

Only partly quantifiable, based on various semantic models (e.g. modal semantics). It requires meaning, relevance, significance and truth-values.

A) Algorithmic theory (Chaitin) defined as the minimum-bit statement that describes a given output.

2.c Syntactic vs. Semantic

M) Mathematical theory of communication (Shannon)

M is insufficient to discuss biological information since the latter seems strongly dependent on the concept of instruction, which is left untouched by M. M at most can provide some useful modelling.

S) Semantic theory (e.g. Bar-Hillel and Carnap, Dretske, Floridi).

S seems irrelevant to discuss biological information since the latter does not contain meanings or truth-values. S at most can provide some metaphorical explanations and heuristics. Things get even worst when S is interpreted semiotically.

A) Algorithmic theory.

Not relevant here.

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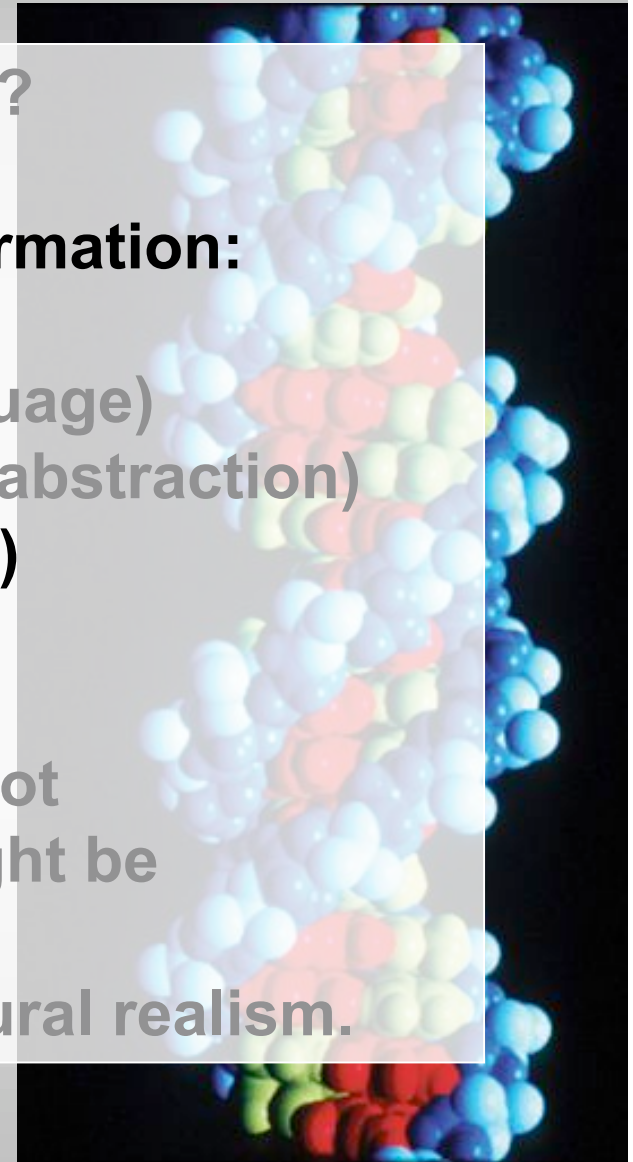
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2.d Ordinary vs. Exceptional

There is a lively debate in information/computer ethics concerning the use of biological (i.e. genetic) information.

In “genetic information”, what seems of great ethical significance is:

- a) the fact that information is easily manipulated; and
- b) the fact that the genetic nature of the information in question is especially sensitive and worthy of ethical regulation.

(b) is called “genetic exceptionalism” or “genetics exceptionalism”. The question is whether genetic information ought to be regulated in a special, distinctive way.

Problem: the predicative vs. attributive confusion creeps in.

Digital information is not information about something digital.

Medical information is information about medical facts.

Combined cases: military information is both information about something military and, because of this, of military nature in itself.

2.d Ordinary vs. Exceptional

P (predicative) and A (attributive) are either independent, or, when they are not,

P cannot depend on A, but rather A depends on P.

The priority thesis of the predicative over the attributive nature of “biological”: a-biological information is so because it is p-biological.

If the priority thesis is correct, then “genetic exceptionalism” is justified not semantically, but ontologically:

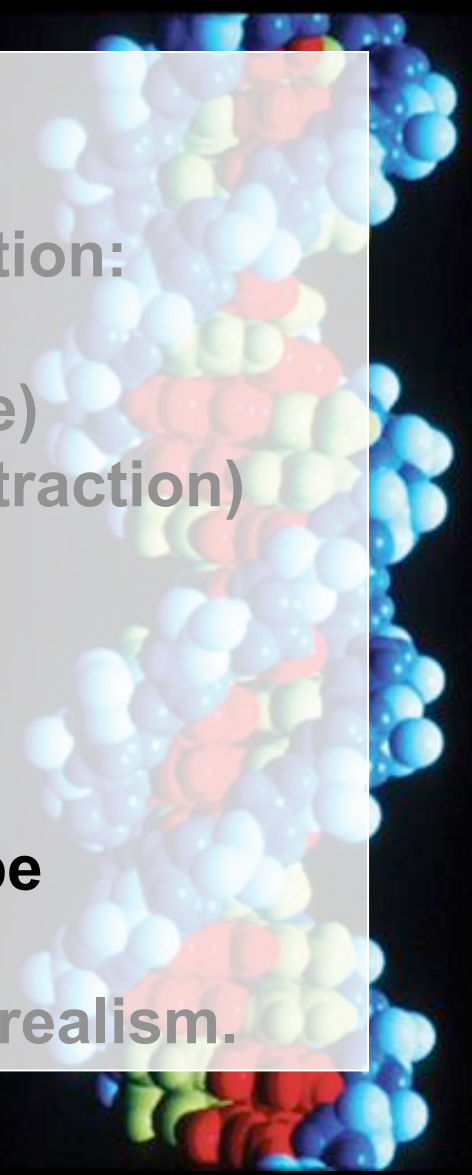
Genetic information ought to be regulated in a special, distinctive way because of what it is in itself, not because of what it is about.

What could p-biological information be in itself?

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3.a What biological information is not

Biological information in the predicative sense is procedural.

DNA contains the genetic code, precisely in the sense that it contains genes which code for the development of the phenotype. So DNA contains genetic information, roughly like a CD may contain some software.

But the genetic code, or better the genes, are the information itself.

Genes do not send information, no more than a password sends any information to the system it interacts with. They work or they don't.

Genes do not contain information (like envelopes or emails), no more than a performative does: "I promise to come at 6" does not really describe (constative function) or contain a promise, it rather does something, i.e. it effects the promise itself through the uttered words.

So genes are not information in a semantic-descriptive-constative sense, and they do not merely contain or encode instructions, as a string of lines and dots may encode a message in Morse alphabet.

3.b What biological information might be

Ontic interpretation: genes are the instructions, and instructions are a type of effective information (recipes, software, commands).

Slogan: in the genetic code, the medium is the message.

Two implications: a shift in the informational paradigm and a unification between two ontological domains (fisica e biologia).

The ontic interpretation relies on the procedural programming one.

Genes are dynamic procedural structures that control and guide organisms' development.

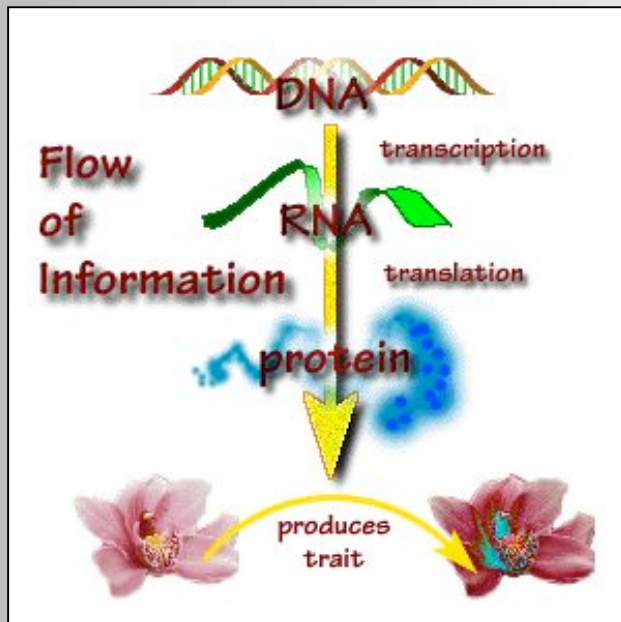
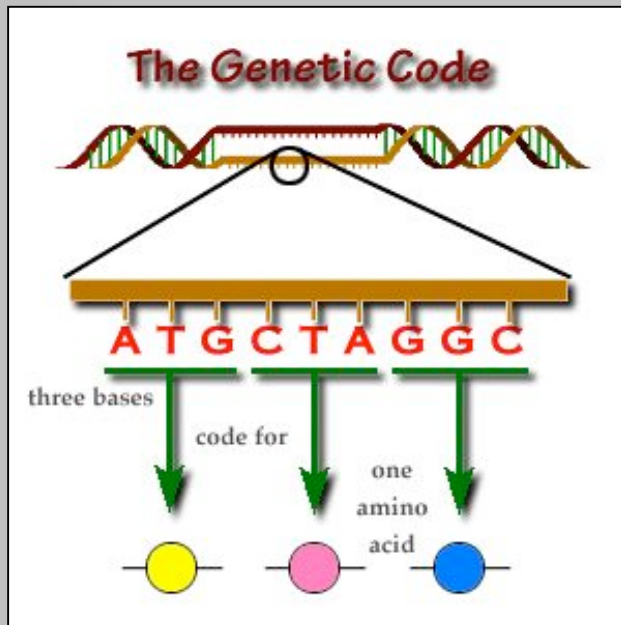
Dynamic procedural structures are a special type of informational entities, those that are in themselves instructions, programs or imperatives.

Cf. imperative programming (aka procedural programming), where statements change a program state and programs are a sequence of commands for the computer to perform.

Each step (each base) is an instruction, and the physical world holds the state that is modified by the instruction.

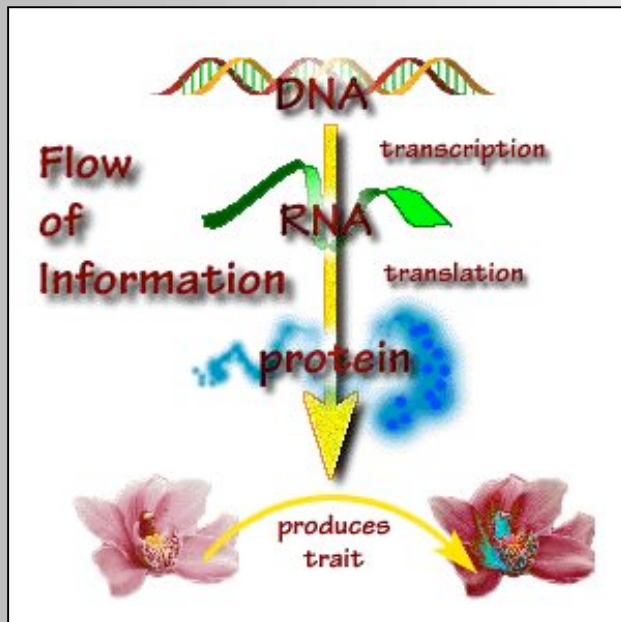
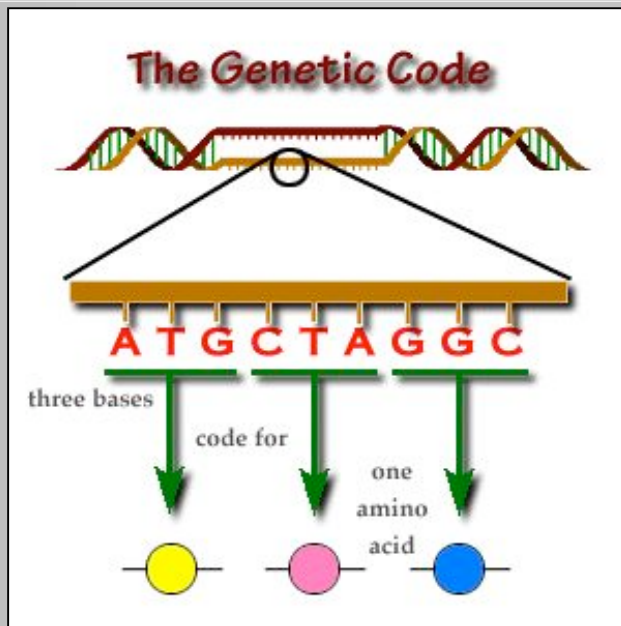
The relation between instructions (genes, imperative programs, recipes) and the outcome is functional-causal and nomic.

3.b What biological information could be



The genetic code (necessary instructions) for building a protein macromolecule is stored on one of the two strands of a DNA molecules as a linear, non-overlapping sequence of the nitrogenous bases Adenine (A), Guanine (G), Cytosine (C) and Thymine (T). These are the "alphabet" of letters used to write the "code words". The genetic code consists of a sequence of three letter "words" (triplets or codons), written one after another along the length of the DNA strand. Each code word is a unique combination of three letters that are eventually interpreted as a single amino acid in a polypeptide chain. There are $4^3 = 64$ code words possible from an 'alphabet' of four letters. One of these code words, the 'start signal' begins all the sequences that code for amino acid chains. Three of these code words act as 'stop signals' that indicate that the message is over. All the other sequences code for specific amino acids. Some amino acids are only coded for by a single 'word', while some others are coded for by up to four 'words'. The genetic code is redundant.

3.b What biological information could be



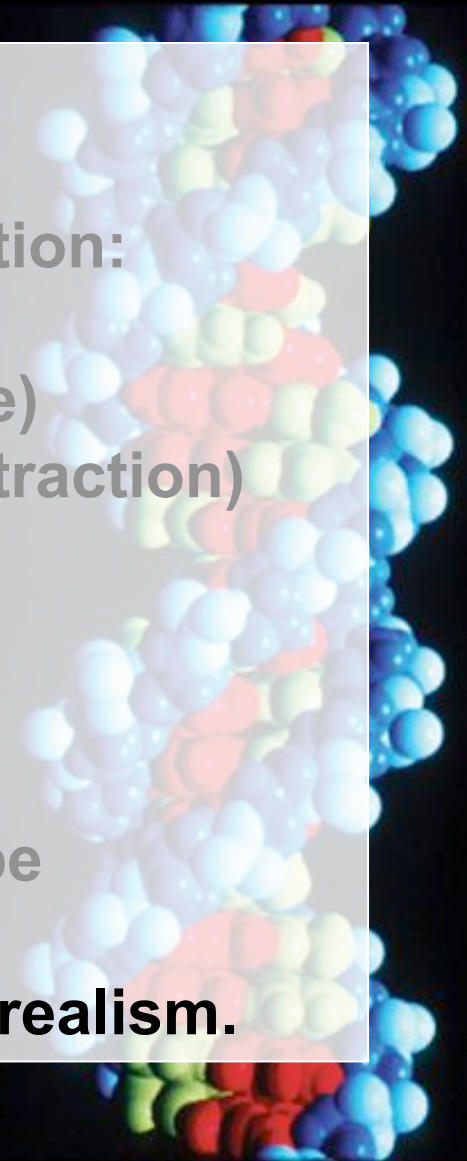
Instructions are copied from the DNA molecule into the form of an RNA molecule (n copies). Each RNA copy (messenger RNA or mRNA) enters the cytoplasm of the cell, where it is converted into the correct linear sequence of amino acids that become a functioning protein. The protein correctly assembled and folded starts working.

Example: the protein in the form of an enzyme catalyst that enhances and speeds up the chemical reaction producing the red pigment. As the protein goes to work the trait is produced. In the example, the trait is the red colour seen in the petals of the flower.

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Conclusion: Bio-informational Structural Realism

The difference between inanimated informational entities and living informational entities is the anti-entropic nature of the latter.

A living system is any anti-entropic informational entity, i.e. any informational object capable of instantiating procedural interactions (it embodies information-processing operations) in order to maintain its existence and/or reproduce itself (metabolism).

One of the great advantages of understanding the genetic code in terms of informational procedural structures is that this allows one to adopt a unified information perspective for the whole reality, both non-living (physis) and living (bios).

This informational ontology is known as informational structural realism.

Informational structural realism is a version of ontic structural realism supporting the ontological commitment to a view of reality as the totality of informational objects dynamically interacting with each other.

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