



10 Γενετική Πληροφορία

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Information in Biology

Key Questions:

- i) why is 'informational' and 'semantic' language so widespread in biology?
- ii) in what sense, if any, do genes contain information?
- iii) is the notion of 'genetic information' just a metaphor?
- iv) what is the relation between (a) information, (b) coding and (c) representation, as used in biology?

Informational/Semantic Language

Maynard Smith:

‘a central idea in contemporary biology is that of information. Developmental biology can be seen as the study of how information in the genome is translated into adult structure, and evolutionary biology of how the information came to be there in the first place’

-‘genetic information’, ‘genetic code’, ‘proofreading’, ‘translation’, ‘mismatch’, ‘copying error’, ‘instructions’, ‘recipes’, ‘signals’, ‘messengers’

-deeply embedded in genetics, evolutionary biology, developmental biology

-clear contrast with **physical** science

-**why** talk this way in biology?

-from a materialist perspective, seems **odd**

Θεωρίες για τη βιολογική πληροφορία

-πληροφορία και **πρόβλεψη**

-> αιτιακή θεωρία πληροφορίας (Shannon information)

Concepts of Information

a) information as **causal covariation**

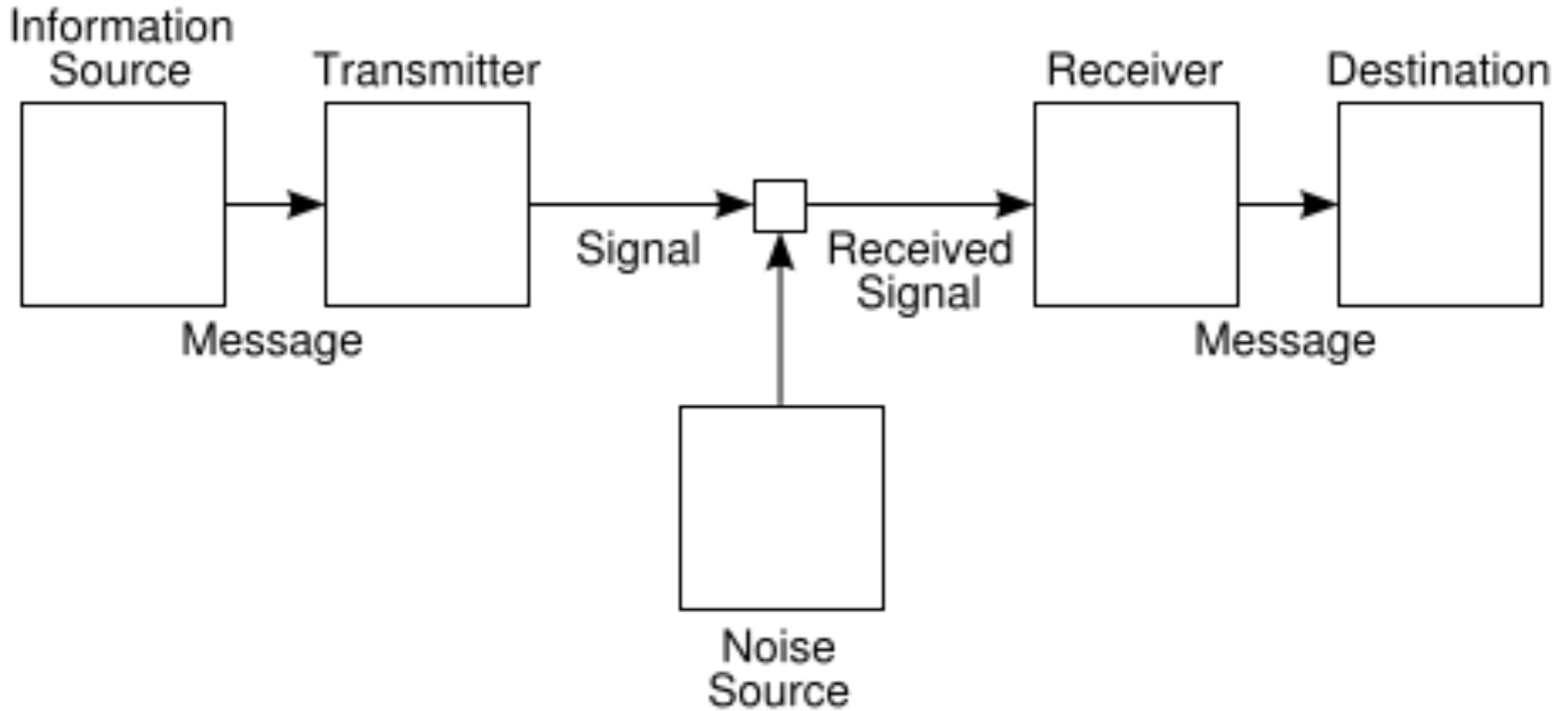
e.g. barometer contains information about weather, gauge contains information about temperature etc.

-> mathematical information theory (Shannon/Weaver)

-> Dretske

-a well-defined notion

-potentially applicable in biology



Shannon information

Concepts of Information

b) 'semantic' information

-information as '**representational content**'

-permits possibility of **error**, misrepresentation

e.g. a portrait contains information about appearance of a historical figure, instruction manual contains information about how the radio works

-**more** than just **covariation**

-some sort of '**intentionality**' is present here

-implicit reference to **conscious intelligence/design?**

Concepts of Information

c) 'symbolic' information

-type of information that possessed by **signs**

-> semiotics

-connection between sign and meaning is **arbitrary**

-e.g. **words** in natural language, some road signs,
carry symbolic information

-> Monod's notion of 'gratuity' in *Chance and Necessity*

Concepts of Information

d) teleosemantic information

-a special sort of **semantic** information

-> some argue: the **only** sort, ultimately

-information derives from **Darwinian function**

e.g. bee's dance contains **information** about food source

-because the dance's **function** is to indicate where the food source is

-> **not** just a matter of covariation

-> a somewhat different gloss:

a biological item (e.g. the dance) owes its form to the operation of **natural selection**

i.e. natural selection explains why the dance is the way it is

-and this is why it contains information

-> **Millikan's** project

Genetic Information

-> **in what sense do genes contain information?**

-causal covariation sense?

yes

e.g. a gene for blue eyes correlates with having blue eyes

similarly, DNA sequence correlates with sequence of amino acids in a protein

BUT many things contain information, in this sense

-not just genes

-e.g. environmental factors that affect development of phenotype

-problem?

-most biologists think that genes are the *unique* carriers of information

Genetic Information

-> **in what sense do genes contain information?**

-symbolic sense?

yes

DNA sequences specify, or code for, proteins

-genetic code: functional relationship between codons and amino acids that make up proteins

(a codon is a triplet of nucleotides; there are four nucleotides (C,A,G,T), hence 64 different codons; these code for 20 different amino acids)

e.g. CAC codes for histidine

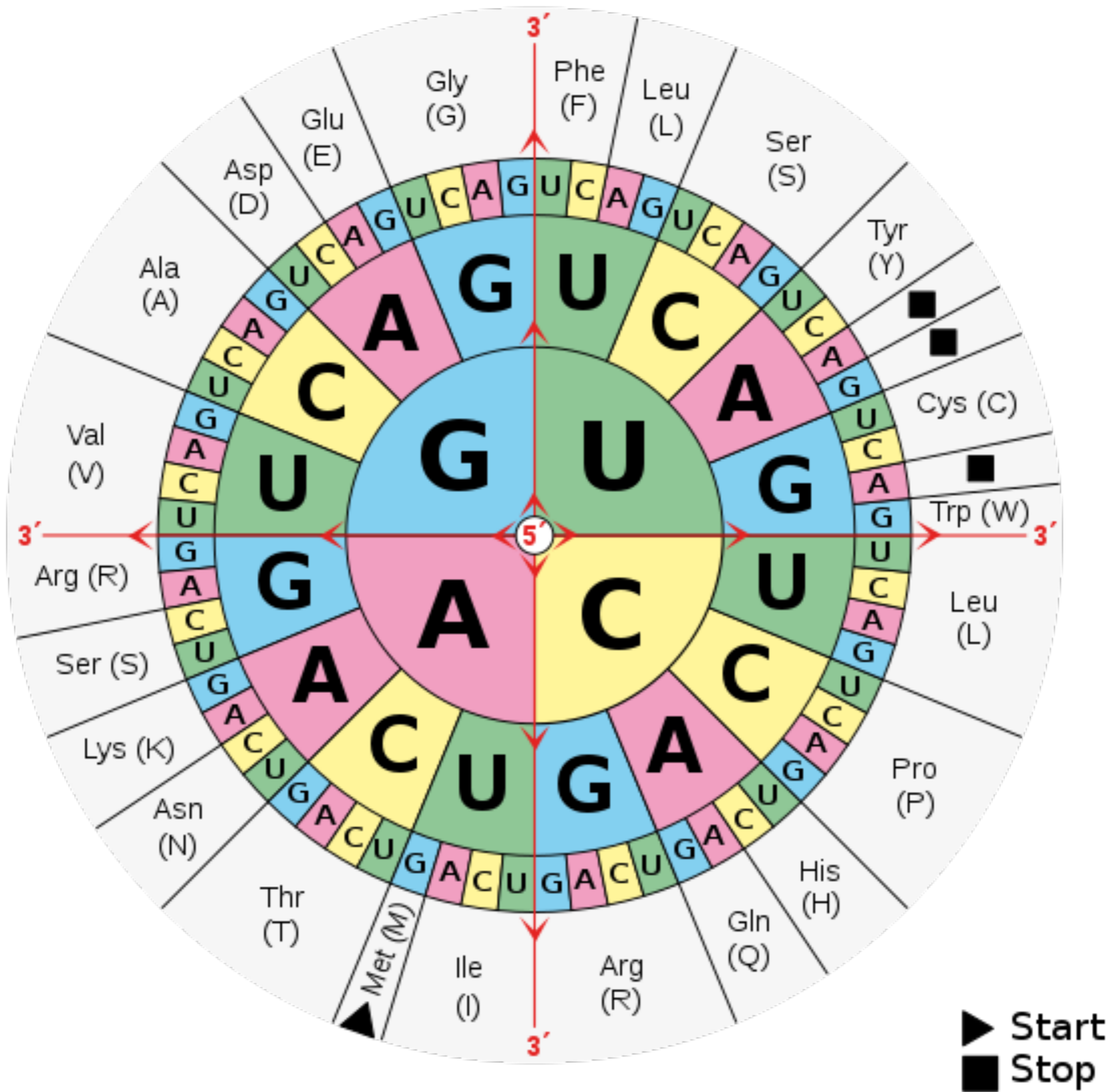
-why is this **coding**, rather than just a **causal** relationship?

-possible answer: because the assignments are **arbitrary**

-hence **symbolic**

-no chemical necessity that CAC should code for histidine, rather than (say) proline

-Monod: it's arbitrary, like human language



Θεωρίες για τη βιολογική πληροφορία

- ο γενετικός κώδικας ως 'αυθαίρετος' (Crick: frozen accident)
- > η σχέση DNA-πρωτεΐνης ανάλογη της σχέσης συμβόλου-νοήματος

- Maynard-Smith: πληροφορία και γονιδιακή έκφραση
- > 'επικοινωνία' μεταξύ γονιδίων

- > **τελεοσημασιολογική** θεωρία (Maynard-Smith, Millikan)

Genetic Information

-does this account for *all* 'informational' speak in biology?

-probably **not**:

i) unclear whether coding implies information (in semantic sense)

ii) genes often said to contain information about **phenotypes**, not just primary protein structure

Genetic Information

-> **in what sense do genes contain information?**

teleosemantic sense?

possibly

-Maynard-Smith: this is the key sense in which genes contain information

-applies best to role of genes in **development**

-> importance of **regulatory** genes -which produce proteins which turn on and off other genes, by binding to them

-so genes are '**sending signals**' to other genes

-> **regulatory** gene sequence and **receptor** sequence can both evolve **independently**

-so there's a '**sender**' and a '**receiver**', both fashioned by natural selection

-a particular regulatory gene has the **function** of switching on/off other genes

-i.e. the DNA sequence of the gene is what it is, because of **natural selection**

-therefore, the gene contains **information**

Genetic Information

Maynard-Smith: 'today, the notion of genes sending signals to other genes is as central as the notion of a genetic code was forty years ago'

-this teleosemantic account explains why **enzymes** don't contain information, but **genes** do, Maynard-Smith argues

-the activity of the enzyme doesn't involve a 'sender' or 'receiver'; it just obeys the **laws of chemistry**

-> this justification for 'information talk' goes beyond the genetic code

-also, goes beyond 'arbitrariness', though this is part of it

Genetic Information

-> does this account for all 'information talk'?

-doubtful:

i) does it actually single out **genes** as unique?

Griffiths: many **non-genetic factors** are information in the same sense

ii) applies well to gene regulation/developmental genetics

i.e. where signalling is at work

BUT what about the idea that the **genome** contains information about the **phenotype**?

-this notion of information seems quite **different**

Θεωρίες για τη βιολογική πληροφορία

-> θέση της αιτιακής ισοτιμίας (causal parity thesis)

Paul Griffiths

DST - developmental systems theory

-> πληροφορία ως καθοδηγητικό περιεχόμενο (instructional content)

-> αιτιακή εξειδίκευση (causal specificity) - Crick information

Θεωρίες για τη βιολογική πληροφορία

Sarkar και Griffiths: η έννοια της πληροφορίας ως **μεταφορά** που δεν έχει κάποιο θεωρητικό ρόλο

-> η έννοια έχει θεωρηθεί ακόμη και **επιζήμια**

-> έννοια του **γενετικού προγράμματος**

-> το κύτταρο ρυθμίζει τη γονιδιακή έκφραση ανάλογα με τις περιβαλλοντικές συνθήκες

-> επιγενετική κληρονομικότητα Jablonka

Further issues

- i) is 'genetic information' a **pernicious** notion?
-> Griffiths, Oyama on link with genetic determinism
- ii) how much informational talk is essential, how much not?
- iii) should we tolerate a **plurality** of 'informational' concepts?

Για περαιτέρω μελέτη:

Godfrey-Smith, κεφ. 9

Maynard Smith (2000) 'The Concept of Information in Biology', *Philosophy of Science* 67: 177-194.

Sterelny & Griffiths, κεφ. 5

Godfrey-Smith & Sterelny 'Biological Information' [SEP]
-> <https://plato.stanford.edu/entries/information-biological/>