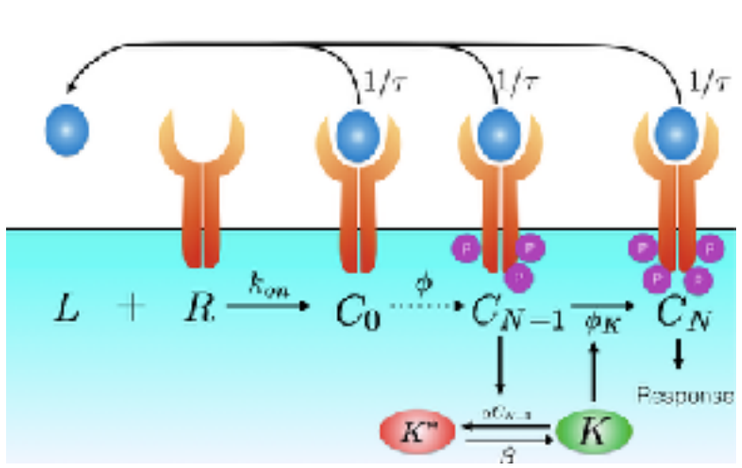
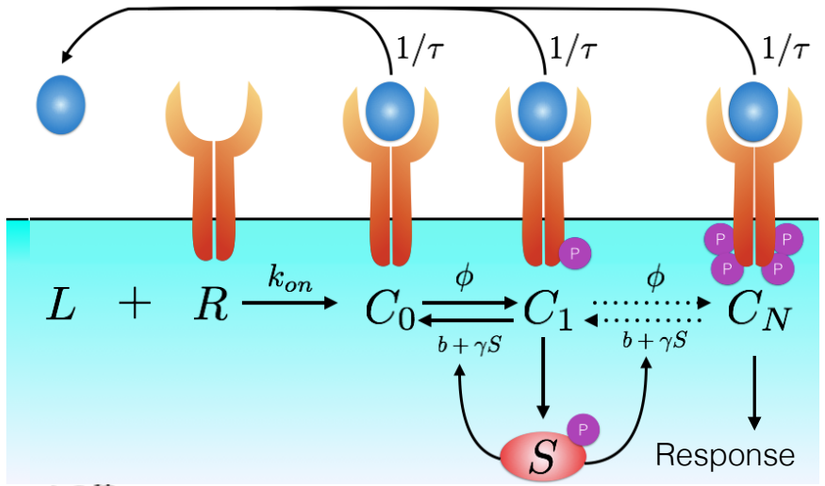
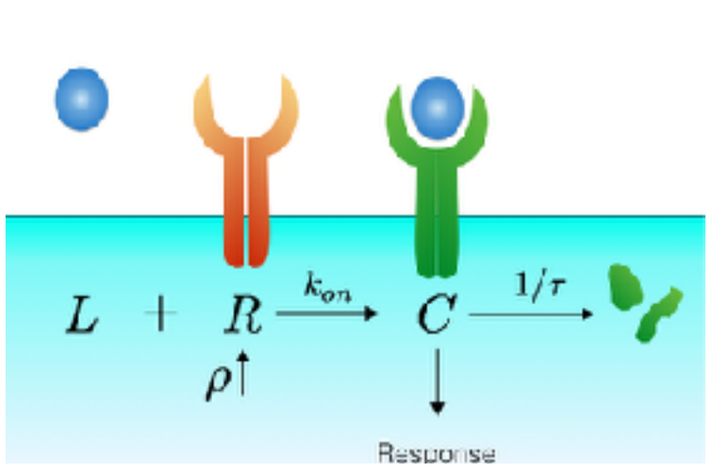
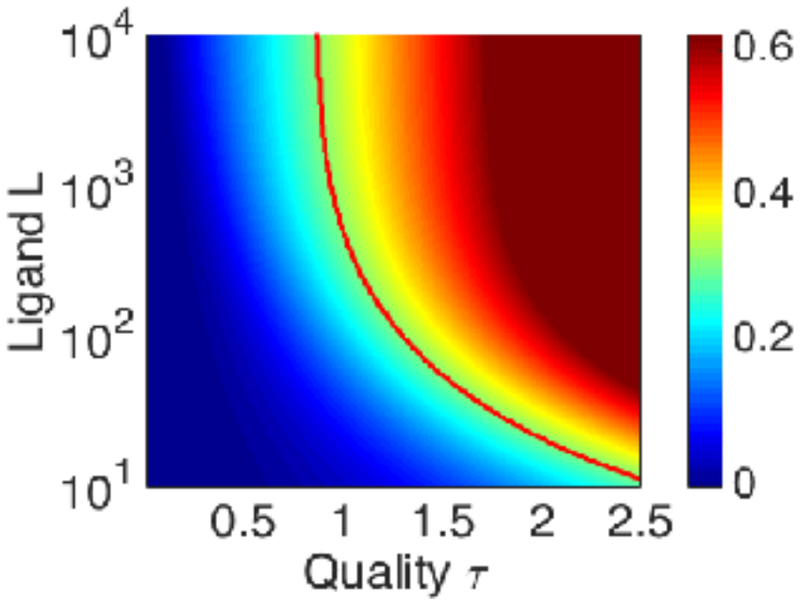
Network structure, function evolution

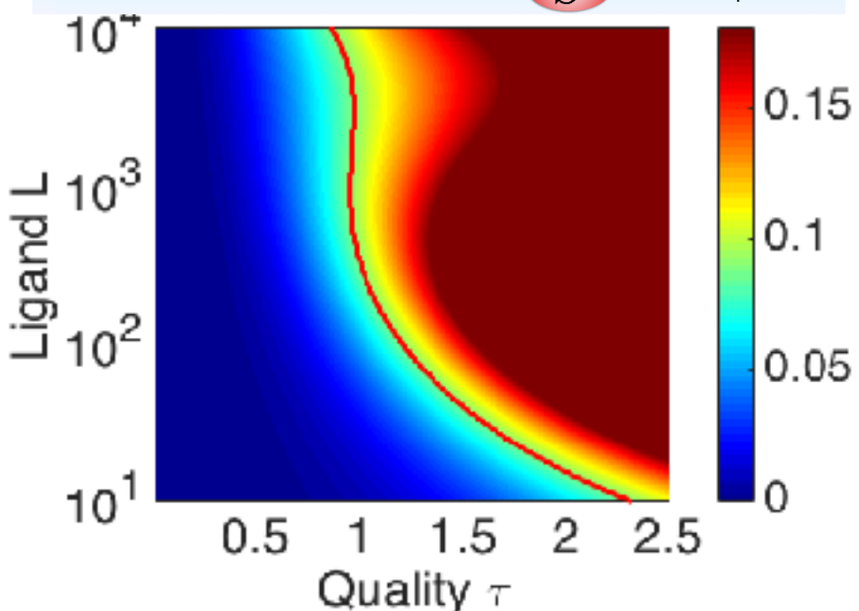
Paul François
McGill University (Montreal) Physics

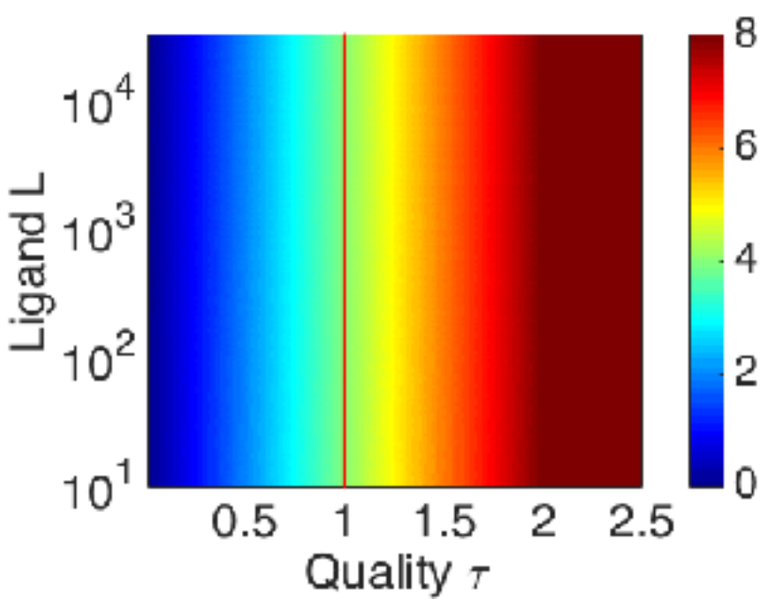












Is evolution purely contingent ?

Gedankenexperiment :
Gould, *Wonderful life*, 1989

Rewind evolutionary tape

Play it back

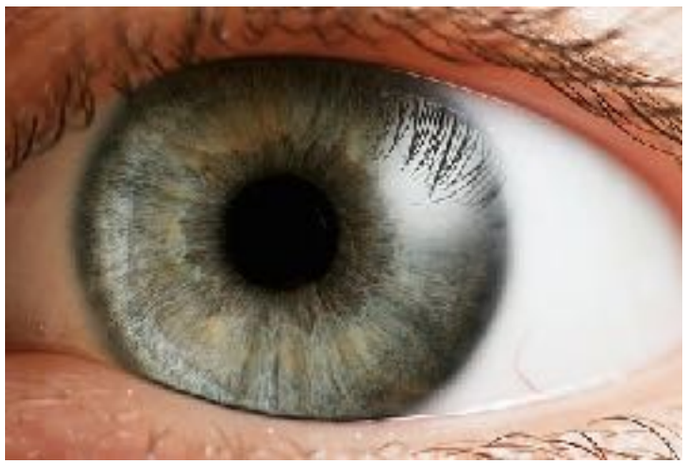
Counter example : convergent evolution of the camera eye

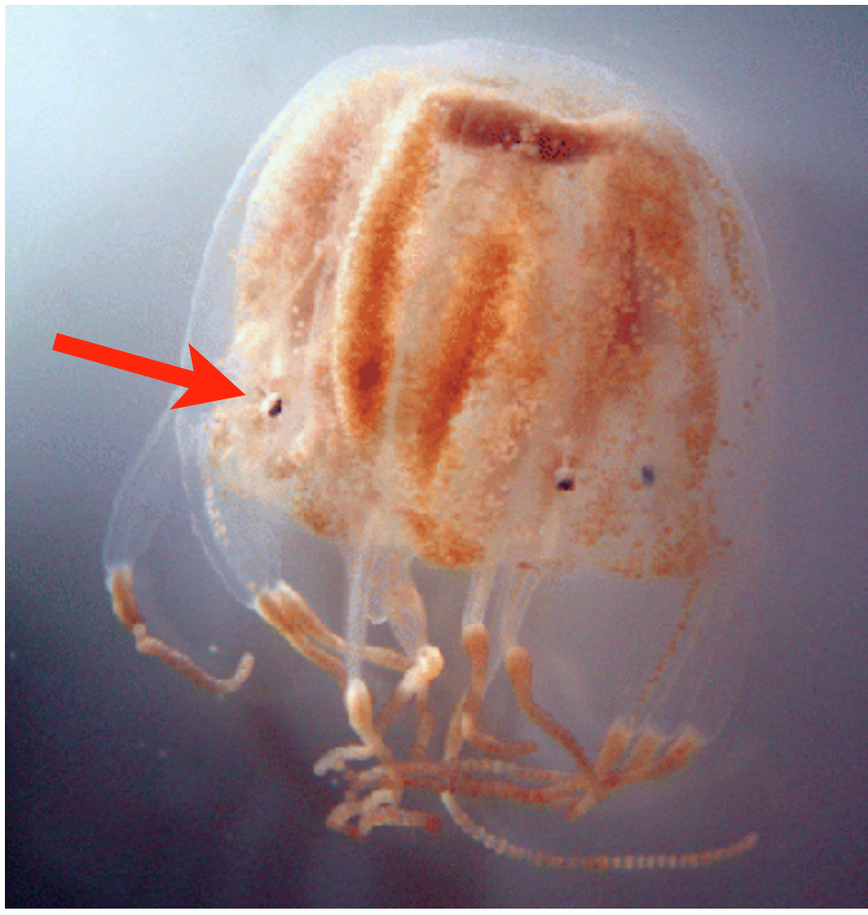
Last common ancestor : photosensitive layer

Cephalopods

Vertebrates

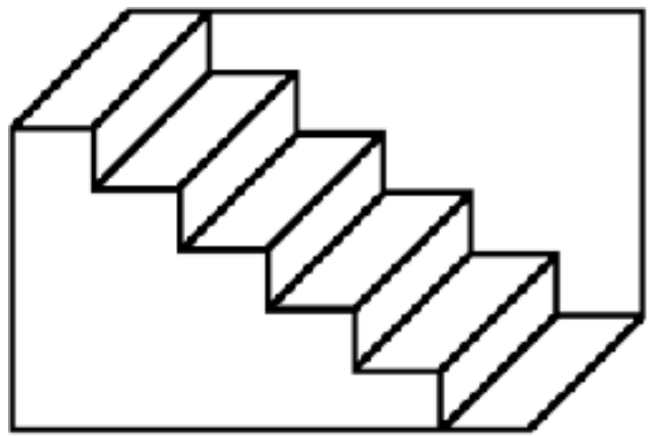
Cnidarians





The problem of the eye

How can complex structures evolve ?

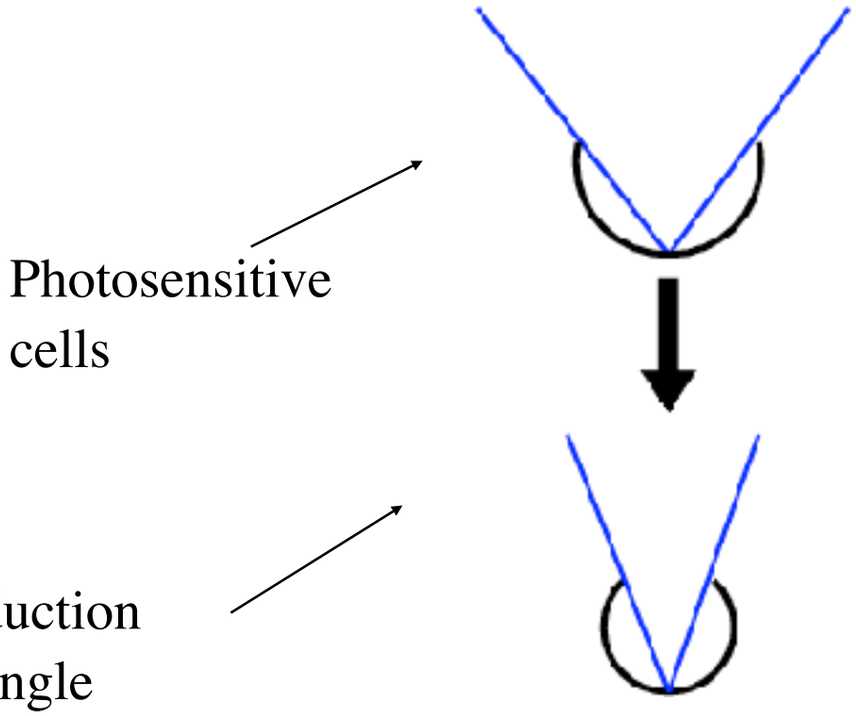


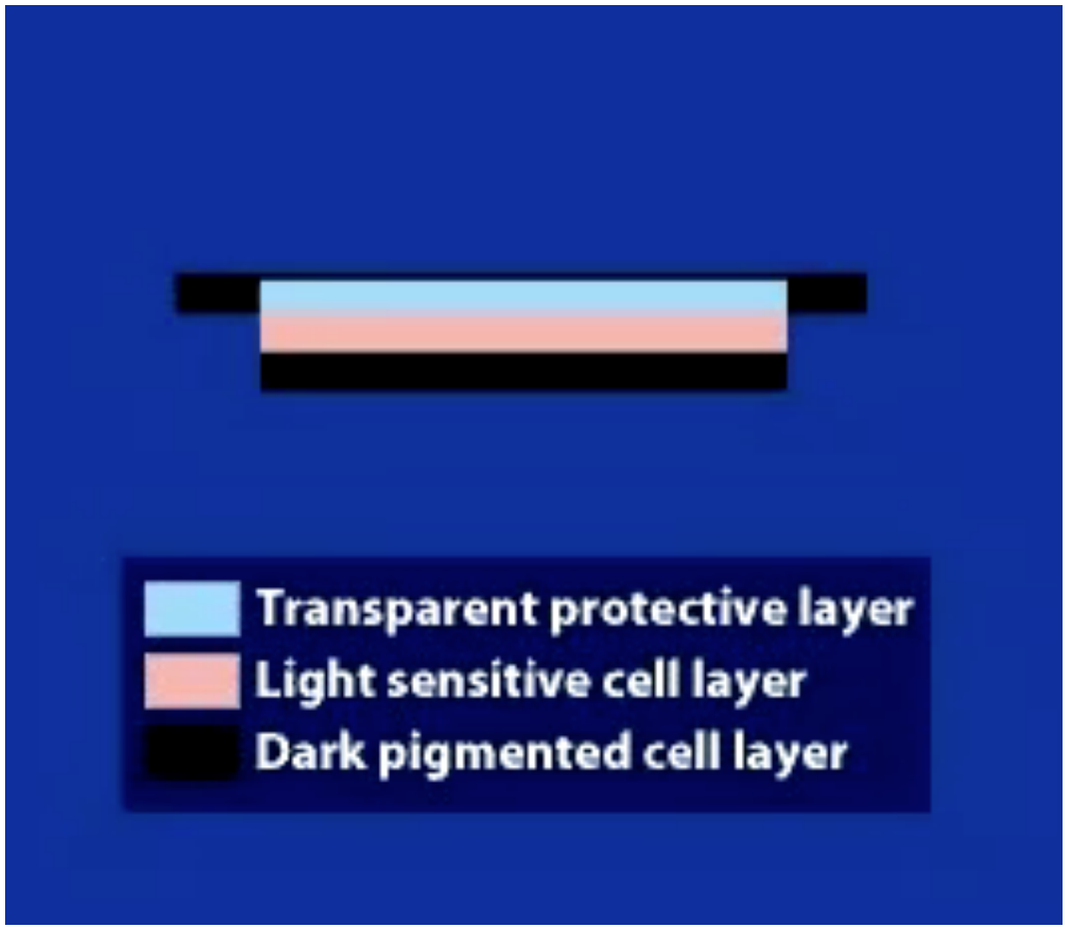
“ (…) if numerous gradations from a perfect and complex eye to one very imperfect and simple, each grade being useful to its possessor, can be shown to exist; (…) then the difficulty of believing that a perfect and complex eye could be formed by natural selection, (…) can hardly be considered real.”

Darwin, The origin of species

Microevolution (“short” time scale, incremental, detailed)	Macroevolution (“long” time scale, punctuated ?, coarse-grained)

Micro to macro evolution





http://www.blackwellpublishing.com/ridley/a-z/Evolution_of_the_eye_b.asp

Physical study of the evolution of the eye **predicts** an **evolutionary pathway** : Nilsson & Pelger, 1994

Lessons:

-one path but not a straight line

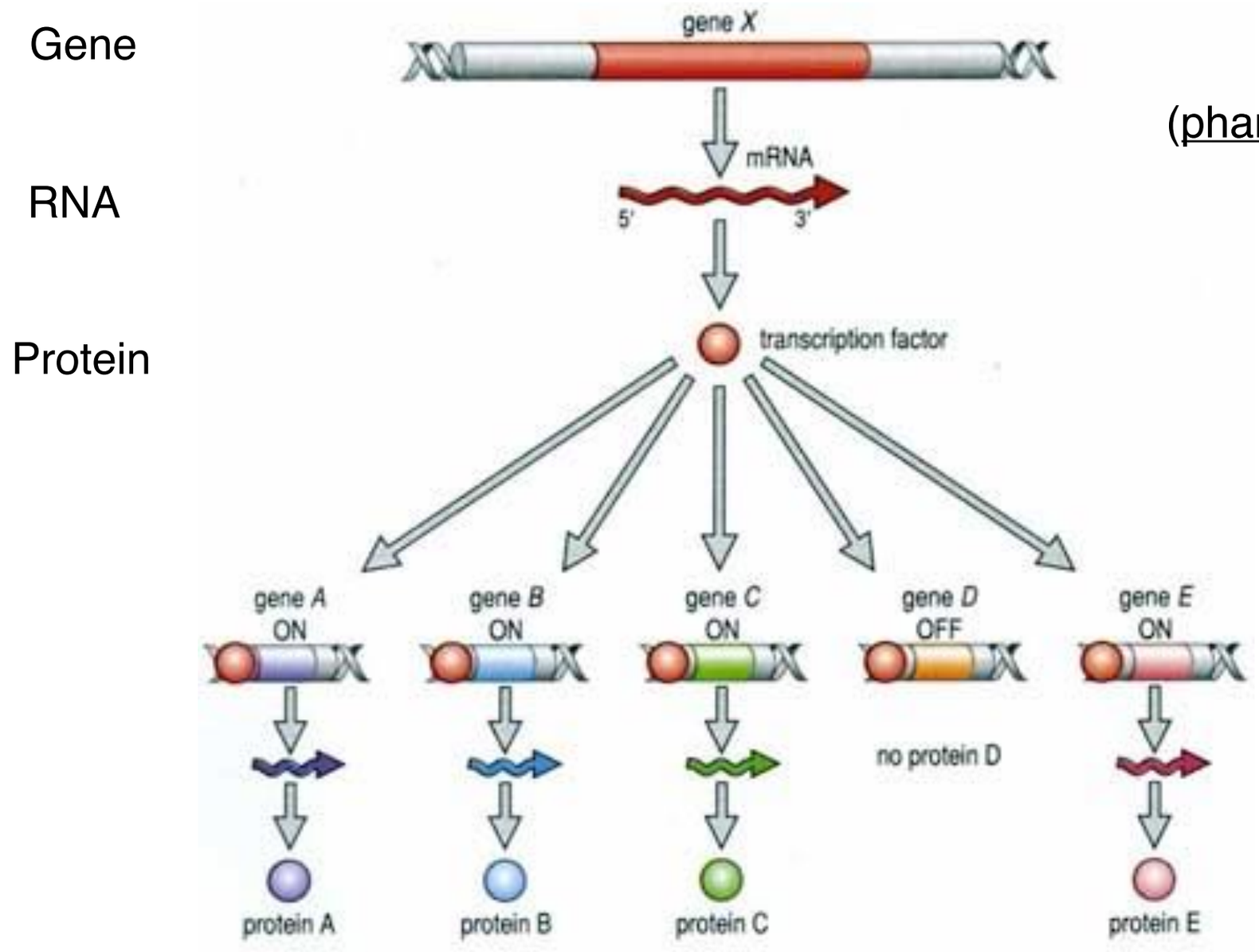
- need for a quantitative theory for **both** the function and the possible changes. Possibly “emergent”

XXth century : central dogma

Gene

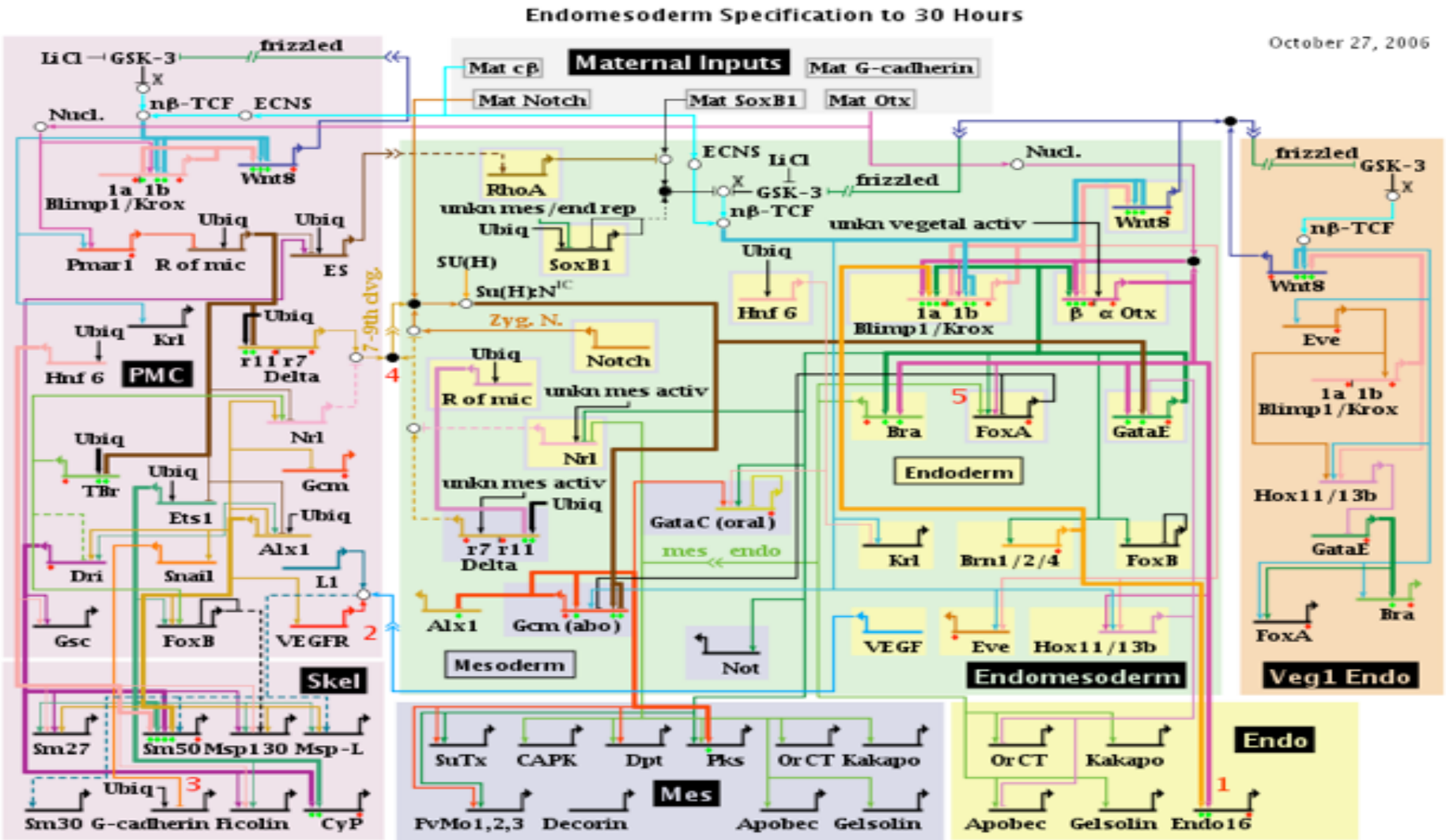
RNA

Protein



(pharyngula.org)

XXIst century : Gene Regulatory Networks (GRN)



Ubiq=ubiquitous; Mat = maternal; activ = activator; rep = repressor;
unkn = unknown; Nucl. = nuclearization; χ = β-catenin source;
nβ-TCF = nuclearized b-β-catenin-Tcf1; ES = early signal;
ECNS = early cytoplasmic nuclearization system; Zyg. N. = zygotic Notch

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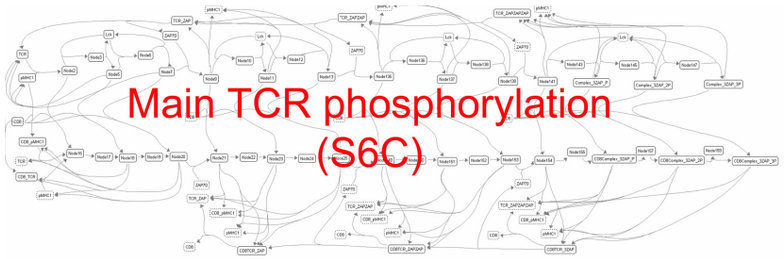
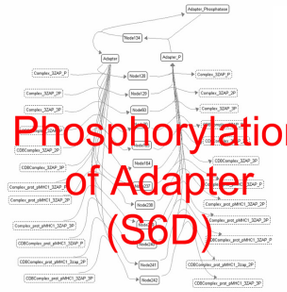
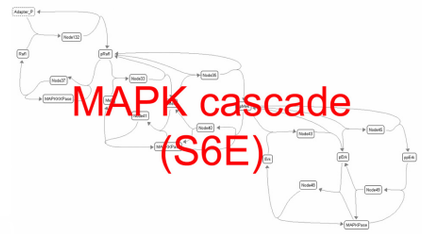
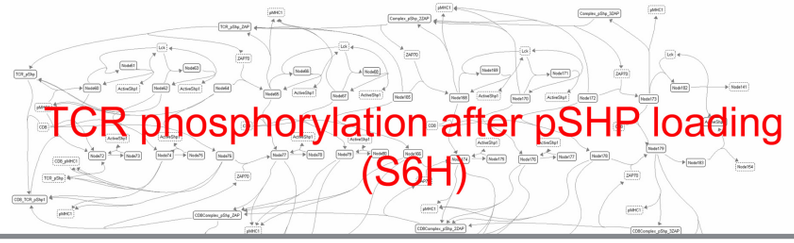
Boulouri &Davidson

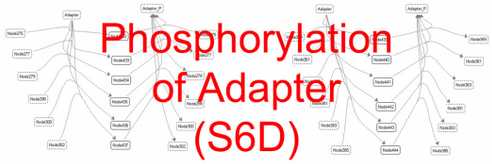
Biochemical network for immune recognition



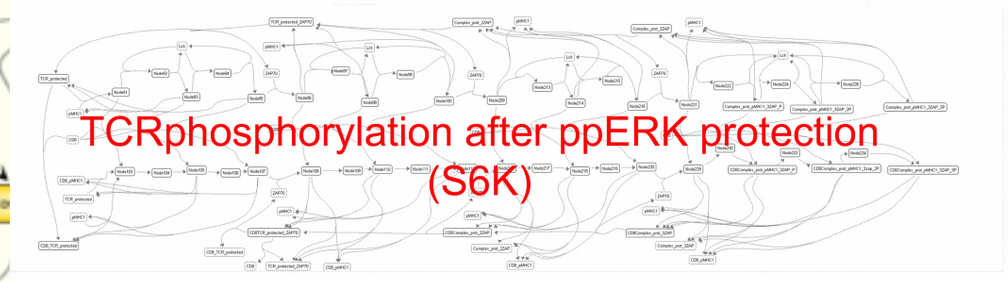


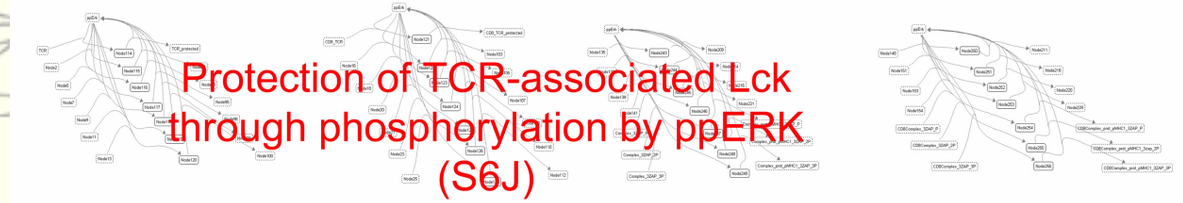




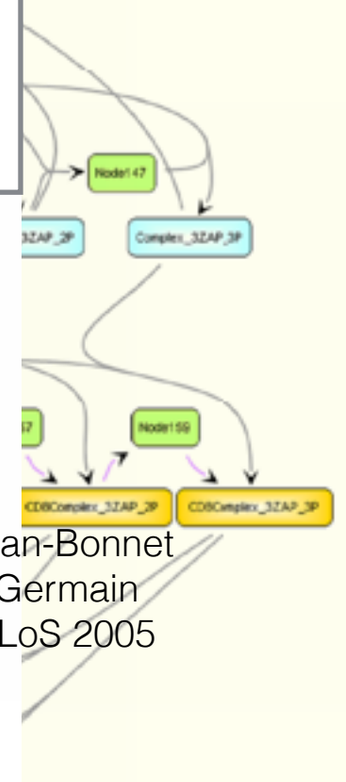


Can we distinguish “biological wood from the molecular tree” ?
(Gunawardena 2013)





Whole network



Altan-Bonnet
Germain
PLoS 2005

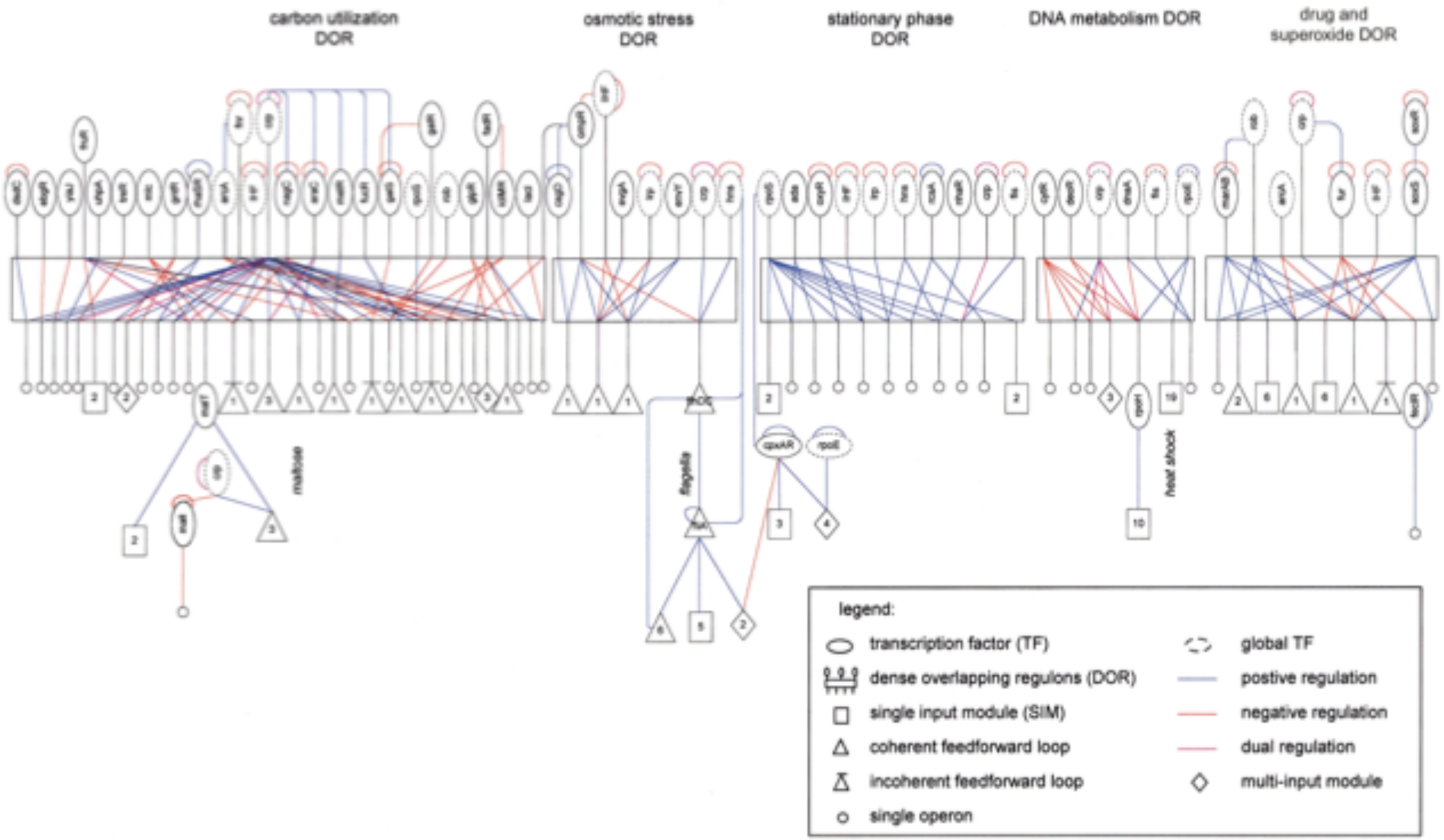
Outline for the next 3 days

- Intro to networks: motifs, dynamics of small modules
- Inverse problems for biology and evo-devo
- Untangling the hairball of the immune networks

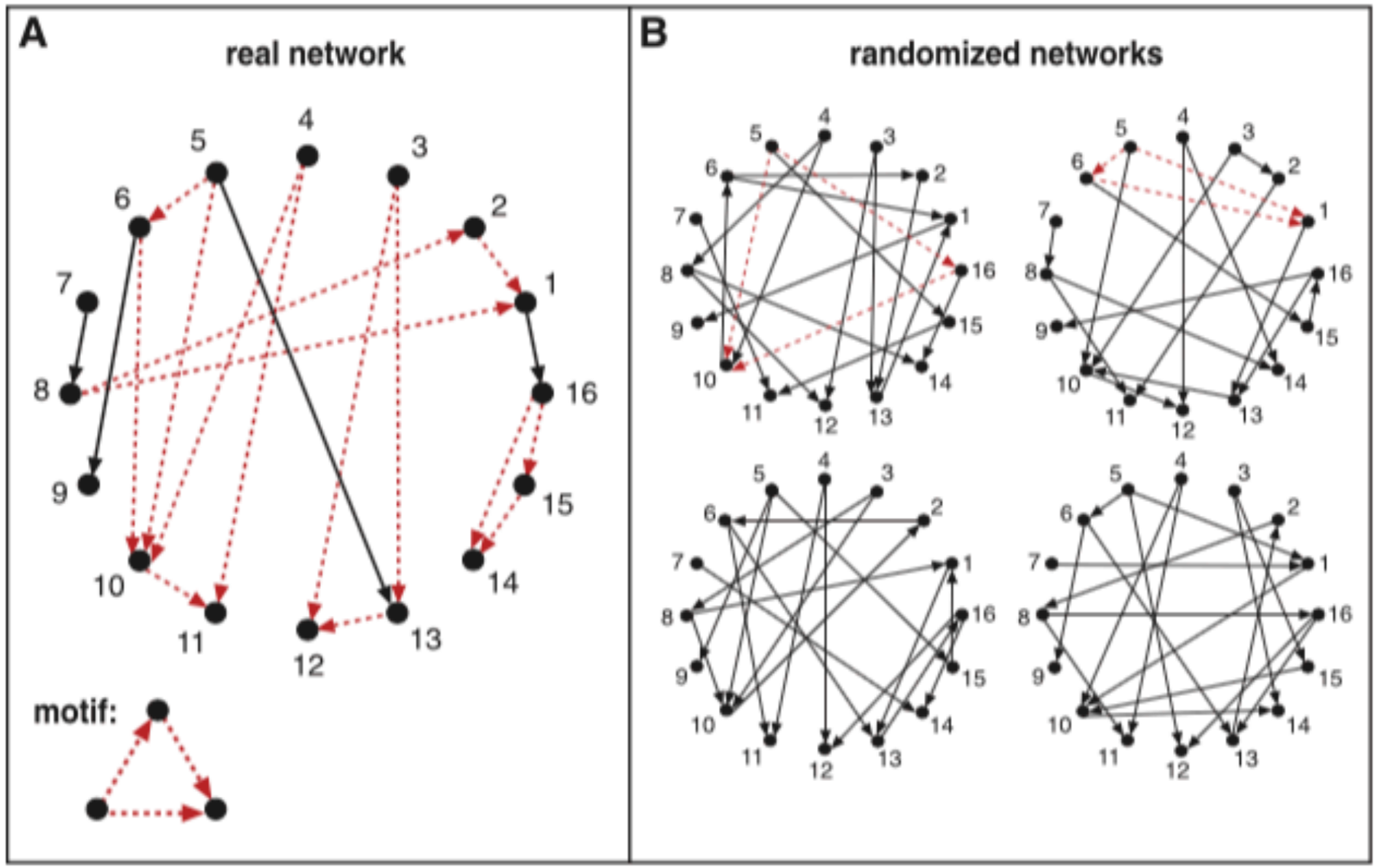
Common themes:

- **“evolvable biological computation”**
- **coarse graining of both networks and function**

E. Coli transcription network: Shen-Orr et al, Nature Genetics, 2002



Statistical discovery of network motifs



Milo et al, Science 2002