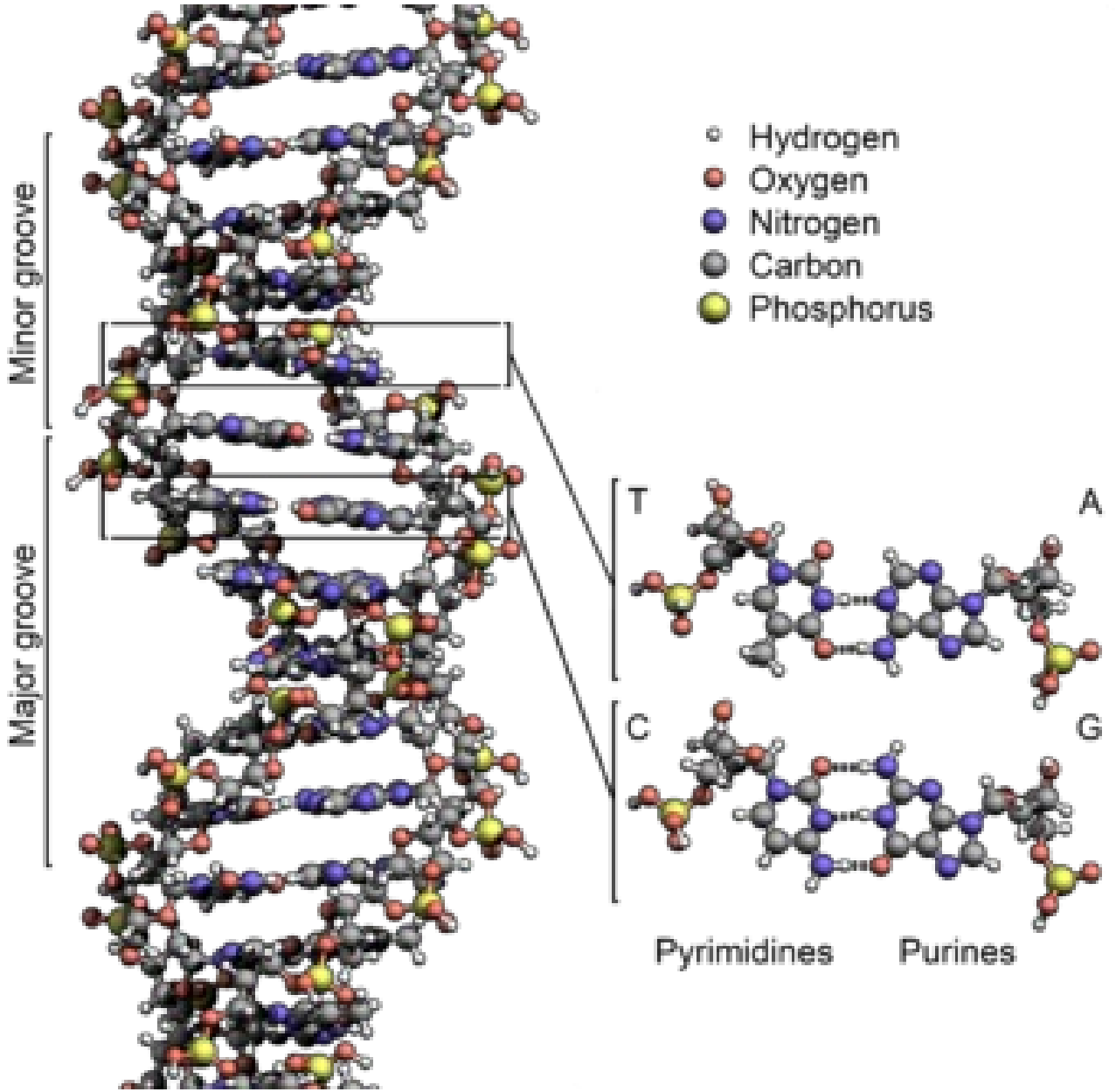
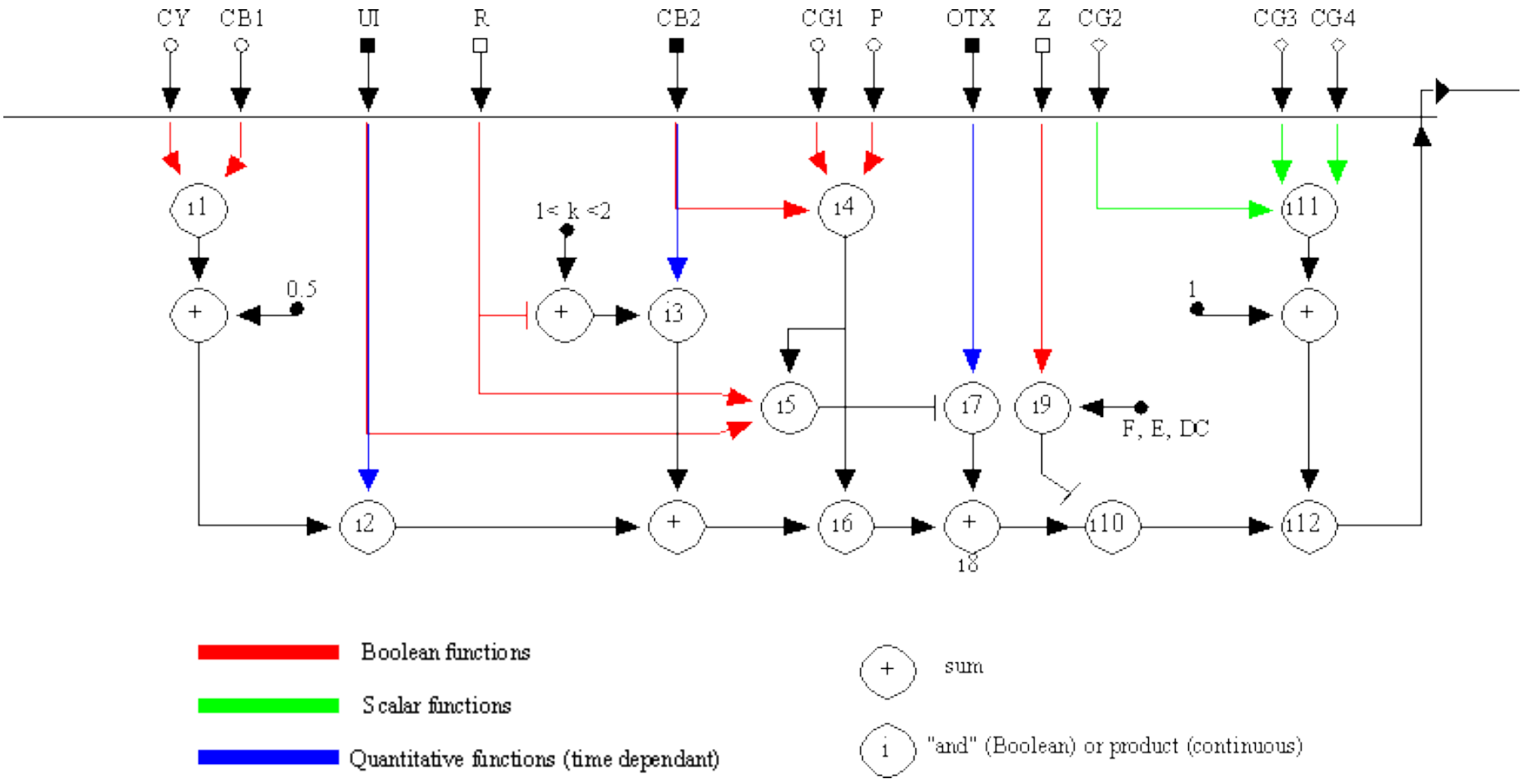
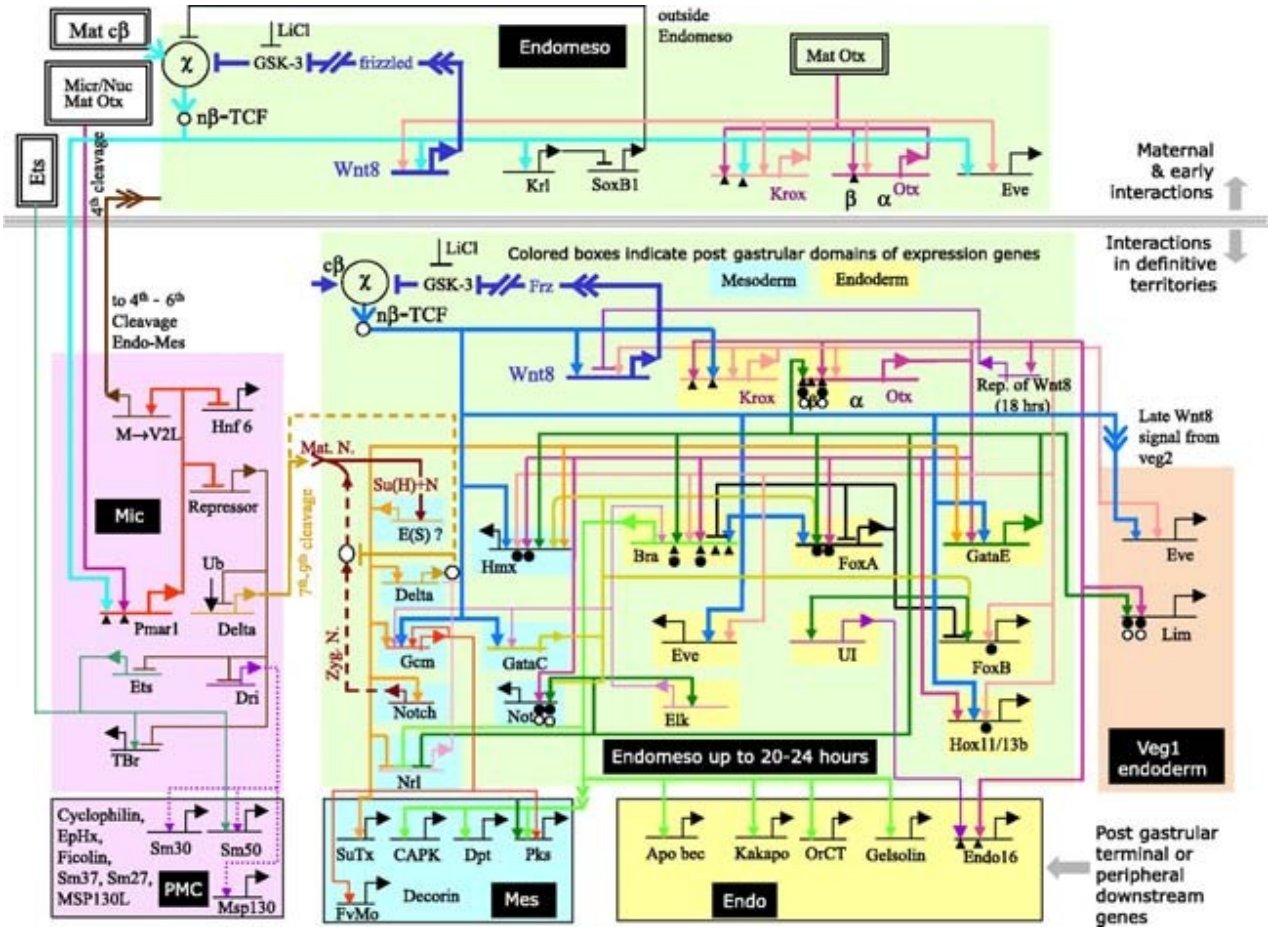
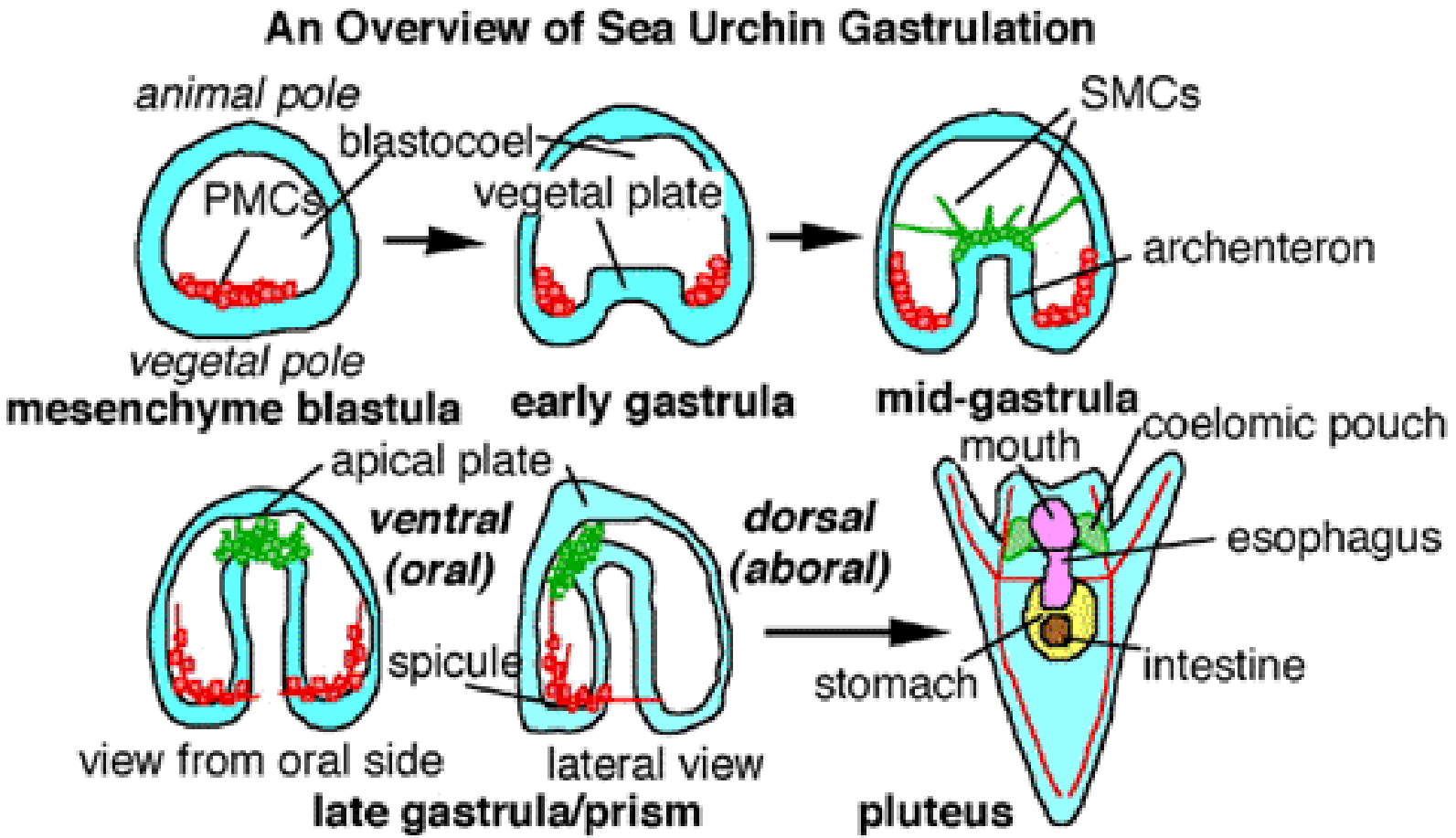

Minor groove
Major groove
Hydrogen
Oxygen
Nitrogen
Carbon
Phosphorus
T
A
C
G
Pyrimidines
Purines

Biological networks

- Some links specified by regions of DNA
- Protein interactions, RNA/RNA, RNA/DNA, RNA/Protein, cell signalling
- Exhibit modular structure
  - Components
  - Scalability

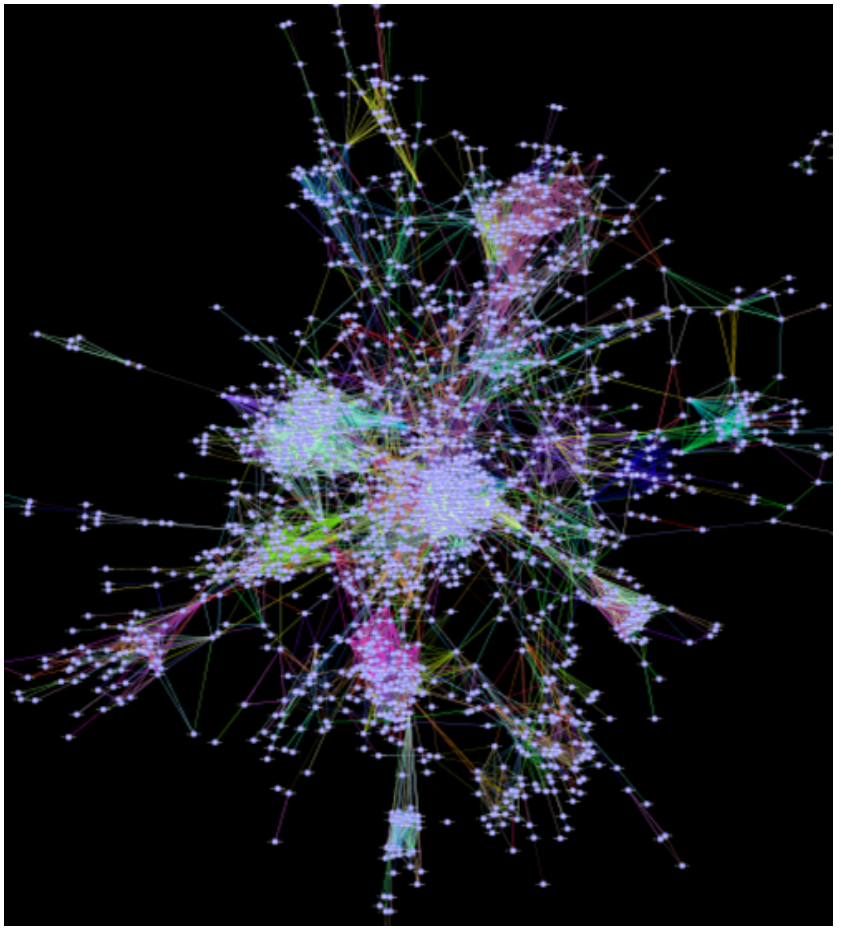

CY
CB1
UI
R
CB2
CG1
P
OTX
Z
CG2
CG3
CG4
i1
i2
i3
i4
i5
i6
i7
i8
i9
i10
i11
i12
+
0.5
1< k <2
1
F, E, DC
Boolean functions
Scalar functions
Quantitative functions (time dependant)
sum
"and" (Boolean) or product (continuous)

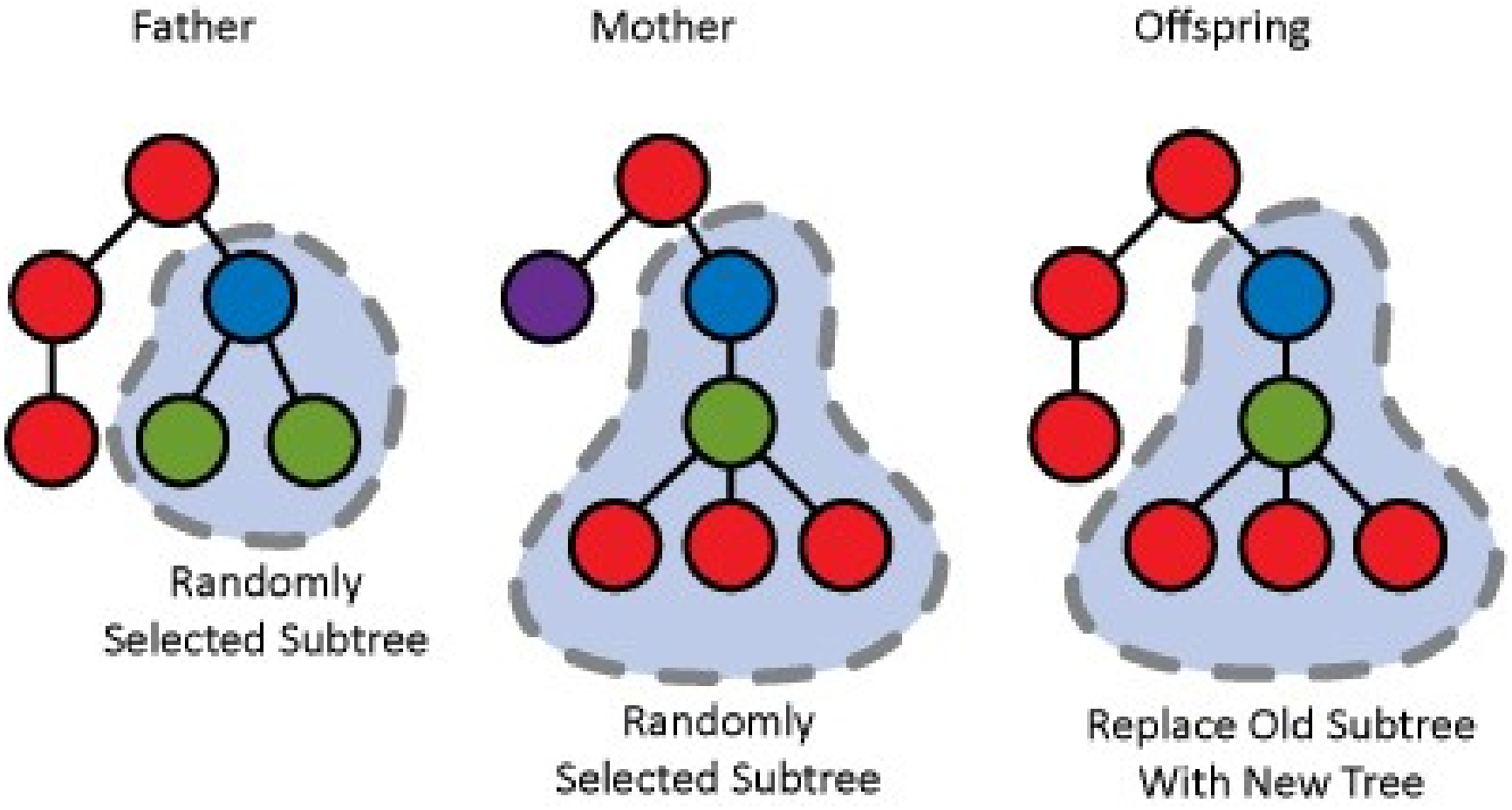

Mat cβ
Micr/Nuc Mat Otx
Ets
4th cleavage
LiCl
GSK-3
frizzled
nβ-TCF
Endomeso
outside Endomeso
Mat Otx
Wnt8
Krl
SoxB1
Krox
β
α
Otx
Eve
Maternal & early interactions
Interactions in definitive territories
Colored boxes indicate post gastrular domains of expression genes
Mesoderm
Endoderm
cβ
LiCl
GSK-3
Frz
nβ-TCF
to 4th - 6th Cleavage Endo-Mes
Wnt8
Krox
α
Otx
Rep. of Wnt8 (18 hrs)
Late Wnt8 signal from veg2
M→V2L
Hnf 6
Repressor
Mic
Ub
Pmar1
Delta
Ets
Dri
TBr
Mat. N.
Su(H)+N
E(S) ?
7th-9th cleavage
Zyg. N.
Delta
Gcm
GataC
Notch
Not
Nrl
Hmx
Bra
FoxA
GataE
Eve
UI
Elk
FoxB
Hox11/13b
Lim
Eve
Endomeso up to 20-24 hours
Veg1 endoderm
Cyclophilin, EpHx, Ficolin, Sm37, Sm27, MSP130L
PMC
Sm30
Sm50
Msp130
SuTx
CAPK
Dpt
Pks
Decorin
FvMo
Mes
Apo bec
Kakapo
OrCT
Gelsolin
Endo16
Endo
Post gastrular terminal or peripheral downstream genes


An Overview of Sea Urchin Gastrulation
animal pole
blastocoel
PMCs
vegetal pole
mesenchyme blastula
vegetal plate
early gastrula
SMCs
archenteron
mid-gastrula
apical plate
ventral
(oral)
spicule
view from oral side
dorsal
(aboral)
lateral view
late gastrula/prism
mouth
coelomic pouch
esophagus
stomach
intestine
pluteus

Modularity

- System built of components




Father
Mother
Offspring
Randomly
Selected Subtree
Randomly
Selected Subtree
Replace Old Subtree
With New Tree

meetup.com/biocoders

@resurgo
peter@fourpartswater.com
@biocoders_uk

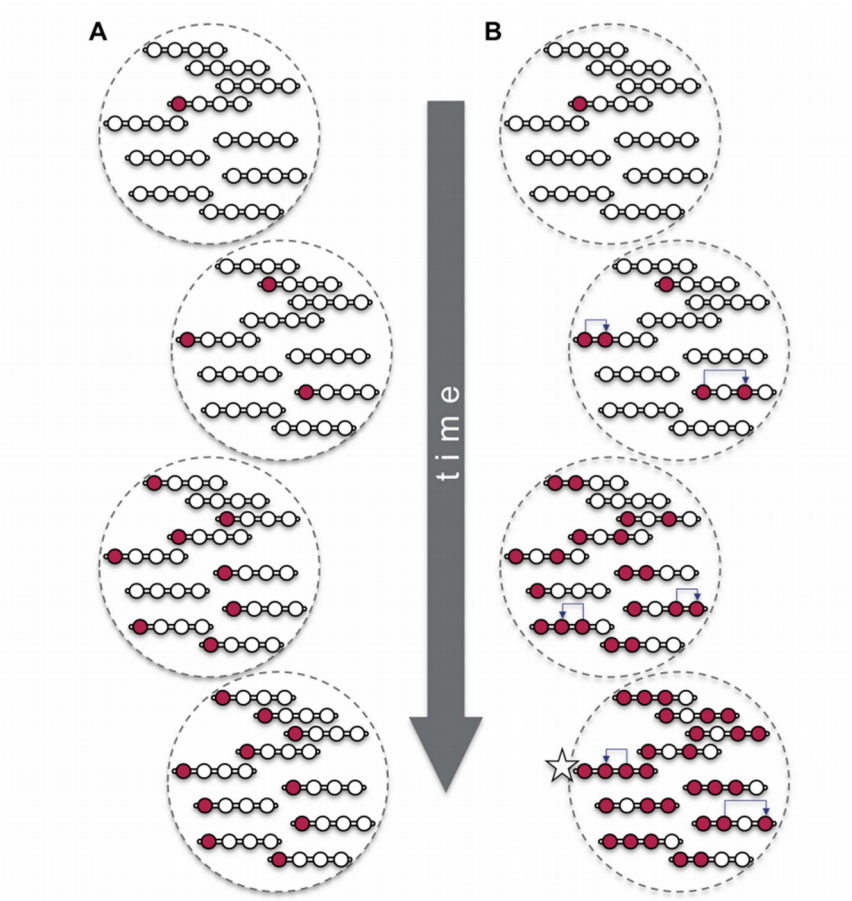
TensorFlow + 3D genome hackathon

Complexity and networks

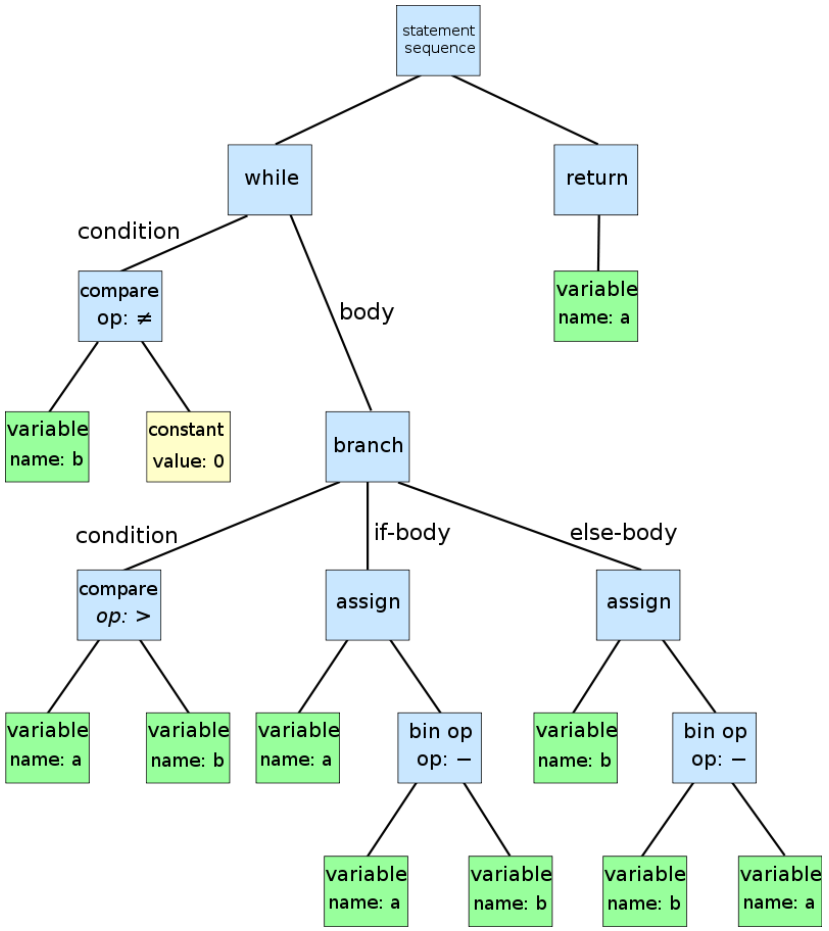
- Small simple networks can lead to complex structure/function = phenotype
- Network links swapped changes higher level behaviour
- Preferential swapping within modules allows scaling → more complex life

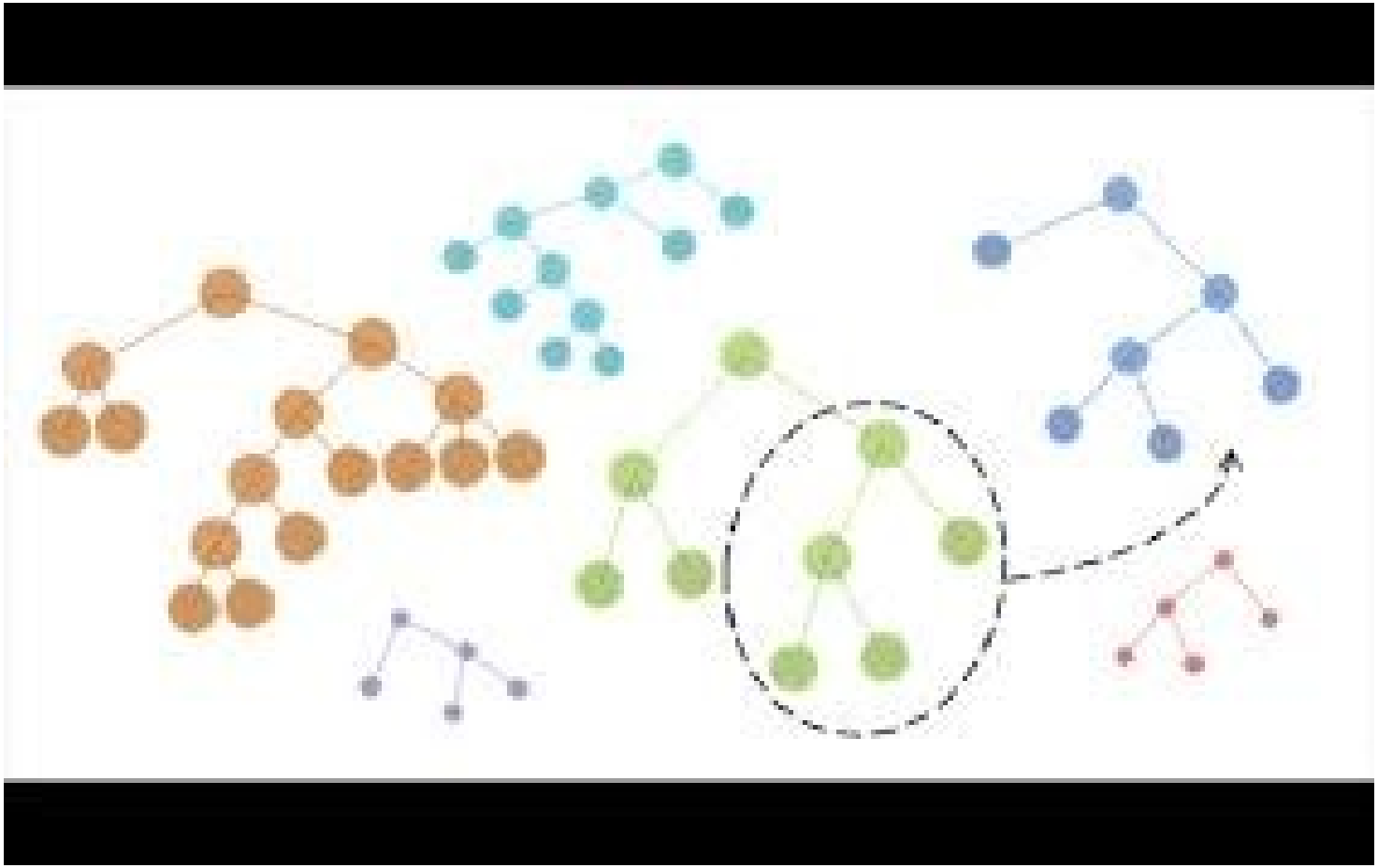
Genetic Programming

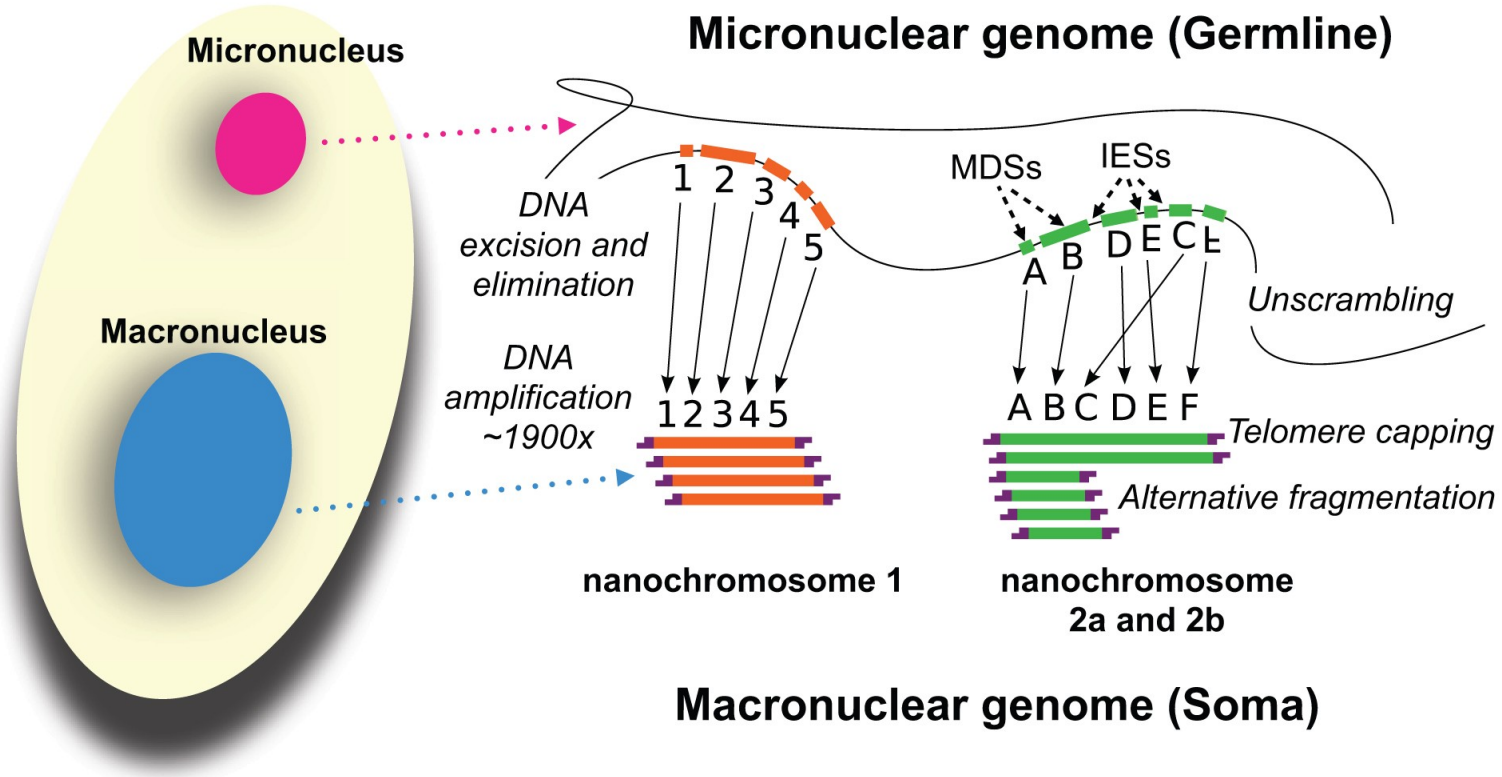
- One type of genetic algorithm
  - Populations of solutions
  - Evolve by natural selection inspired processes
  - Selection, mutation, recombination
- Represent solutions to problems as computational trees
- Human competitive for small systems
  - Breaks patents

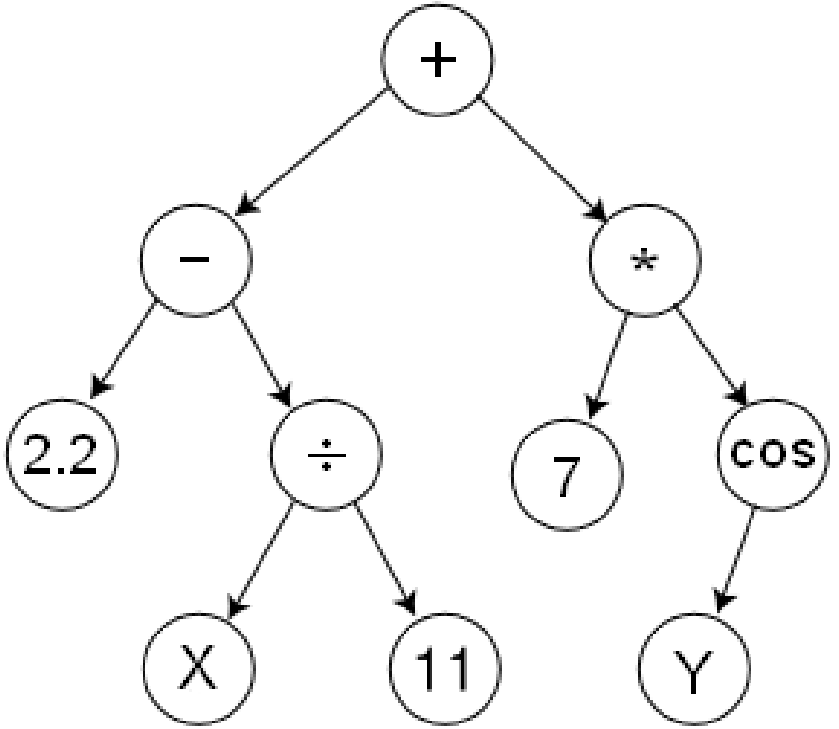

A
B
time

Program as tree





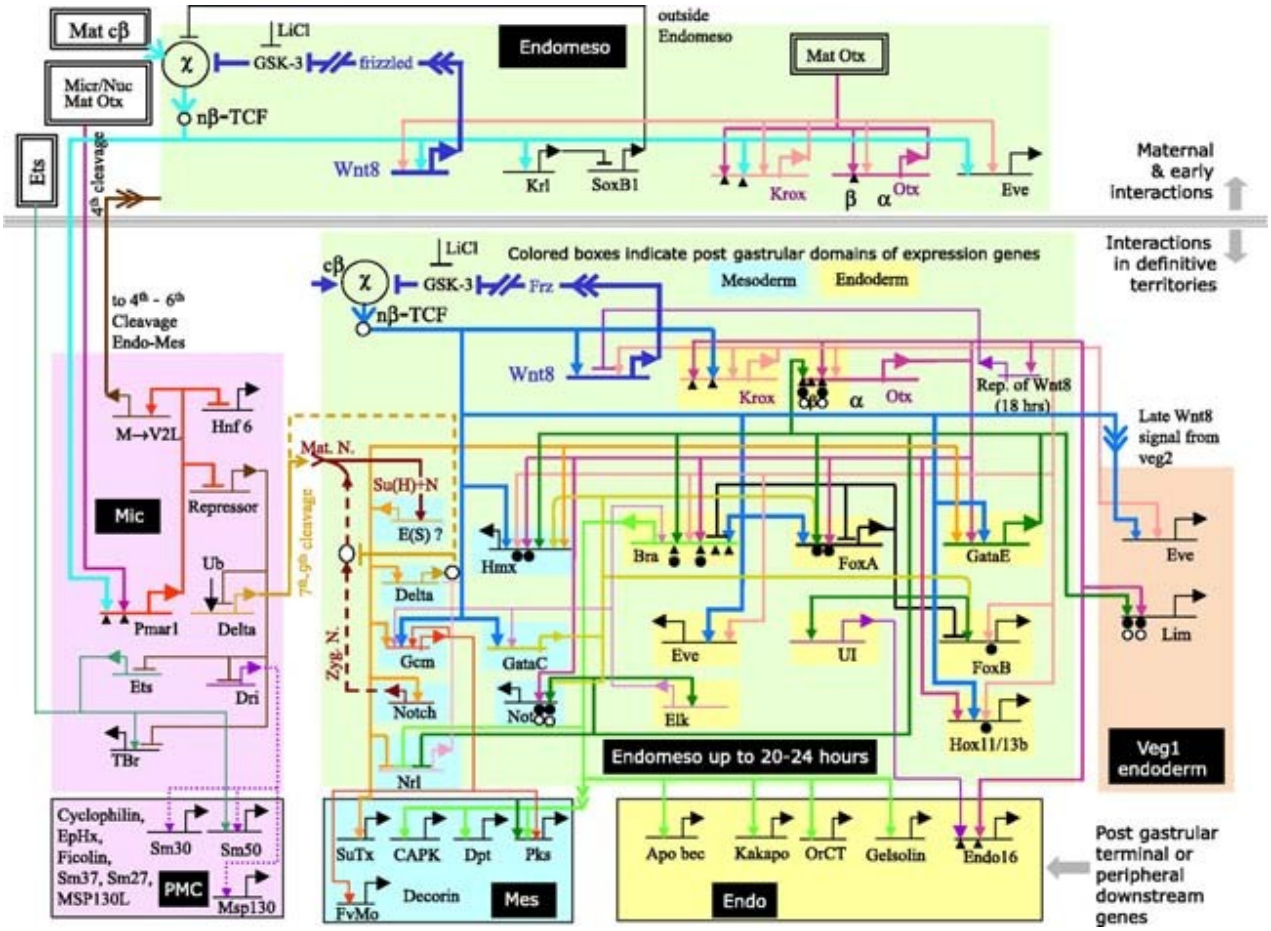

Micronucleus
Macronucleus
Micronuclear genome (Germline)
DNA
excision and
elimination
1 2 3 4 5
MDSs
IESs
A B D E C F
Unscrambling
DNA
amplification
~1900x
1 2 3 4 5
A B C D E F
Telomere capping
Alternative fragmentation
nanochromosome 1
nanochromosome
2a and 2b
Macronuclear genome (Soma)



$$\left(2.2 - \left(\frac{X}{11}\right)\right) + \left(7 * \cos(Y)\right)$$

Scalability

- GP not very scalable
- Specialisation in subtrees broken by swapping
- Network evolution
  - Network connectivity determines behaviour
- Modular evolvability
- How might the genome do this?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GSK-3
frizzled
nβ-TCF
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outside Endomeso
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Krl
SoxB1
Krox
β
α
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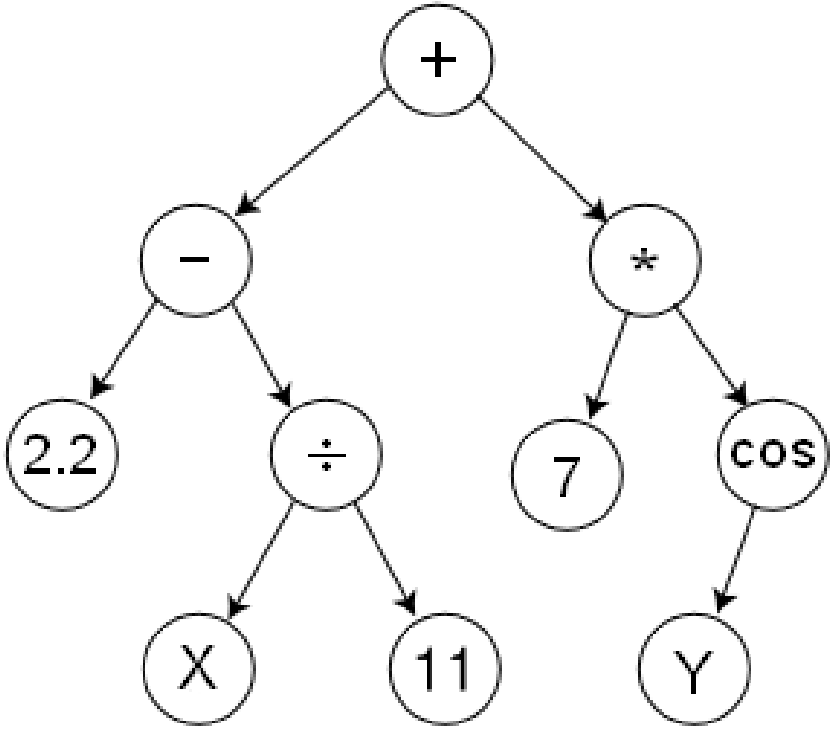
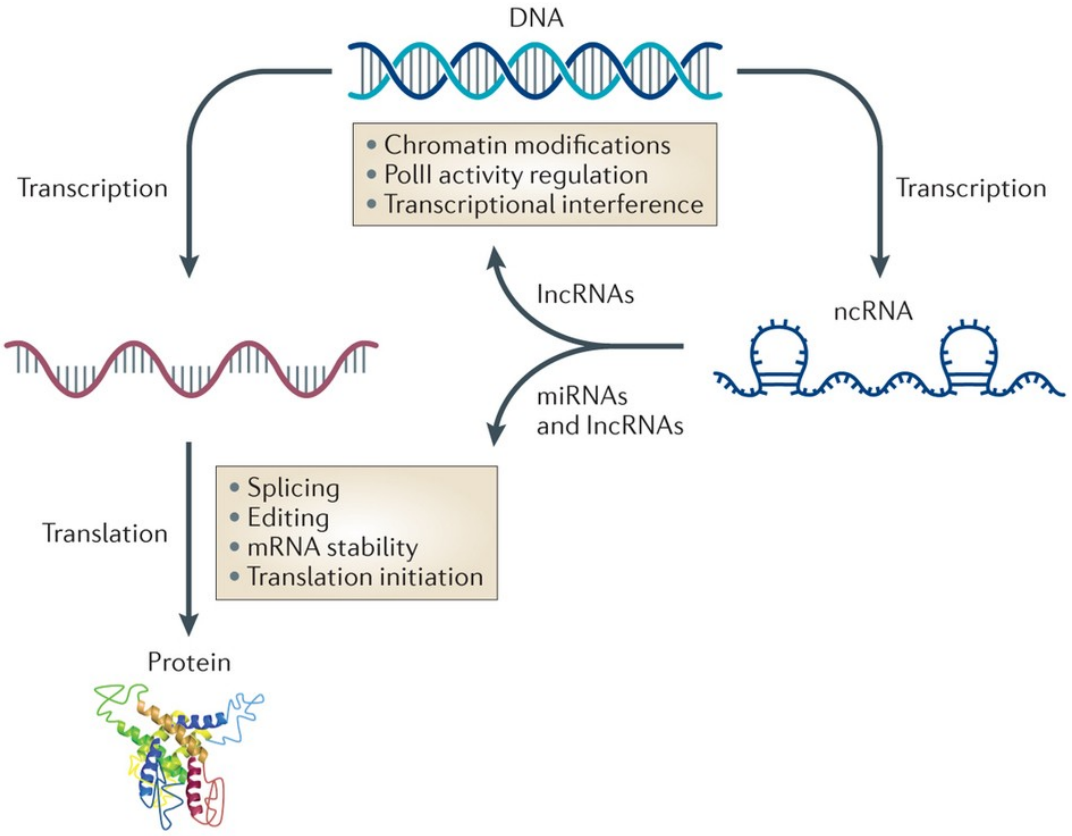
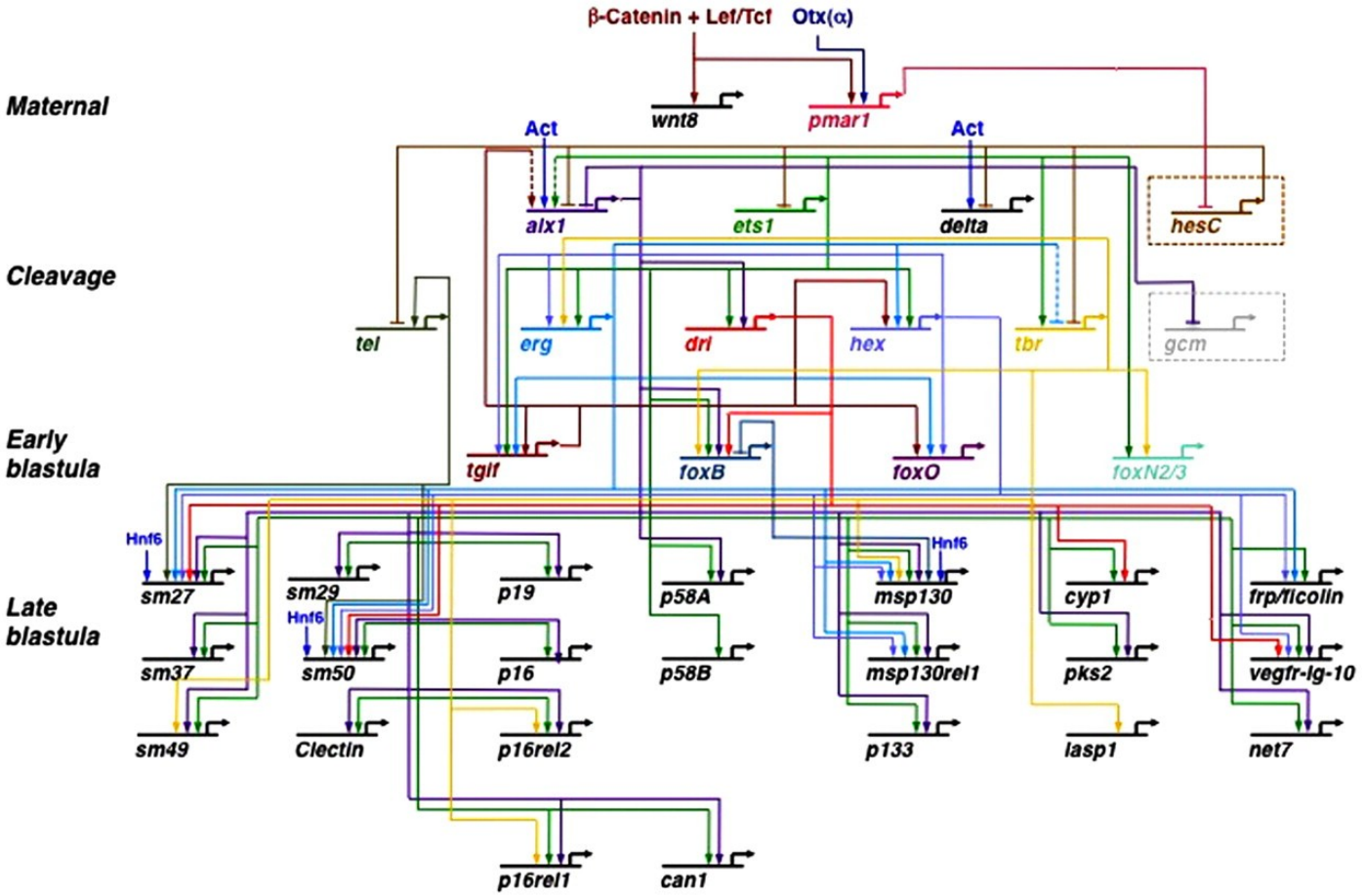
Mic
Ub
Pmar1
Delta
Ets
Dri
TBr
Mat. N.
Su(H)+N
E(S) ?
7th-9th cleavage
Zyg. N.
Delta
Gcm
GataC
Notch
Not
Nrl
Hmx
Bra
FoxA
GataE
Eve
UI
Elk
FoxB
Hox11/13b
Lim
Eve
Endomeso up to 20-24 hours
Veg1 endoderm
Cyclophilin, EpHx, Ficolin, Sm37, Sm27, MSP130L
PMC
Sm30
Sm50
Msp130
SuTx
CAPK
Dpt
Pks
Decorin
FvMo
Mes
Apo bec
Kakapo
OrCT
Gelsolin
Endo16
Endo
Post gastrular terminal or peripheral downstream genes

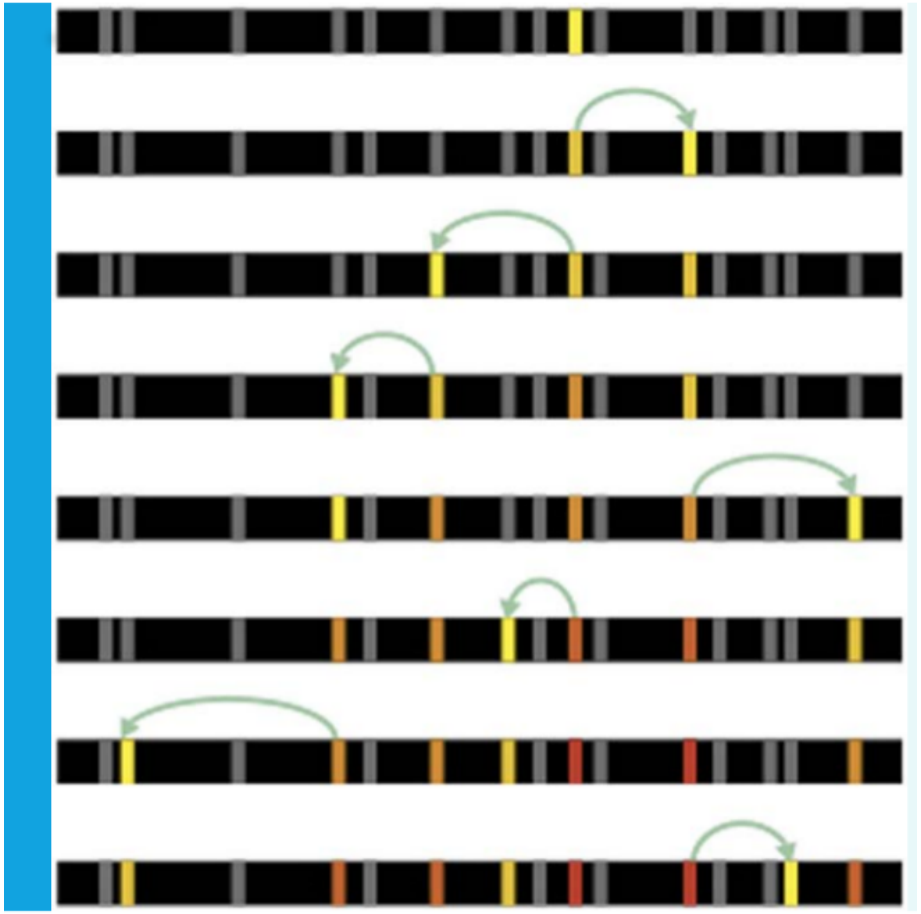


$$\left(2.2 - \left(\frac{X}{11}\right)\right) + \left(7 * \cos(Y)\right)$$



Nature Reviews | Drug Discovery


Maternal
Cleavage
Early blastula
Late blastula
β-Catenin + Lef/Tcf
Otx(α)
wnt8
pmar1
Act
Act
alx1
ets1
delta
hesC
tel
erg
dri
hex
tbr
gcm
tgif
foxB
foxO
foxN2/3
Hnf6
Hnf6
Hnf6
sm27
sm29
p19
p58A
msp130
cyp1
frp/ficolin
sm37
sm50
p16
p58B
msp130rel1
pks2
vegfr-lg-10
sm49
Clectin
p16rel2
p133
lasp1
net7
p16rel1
can1



Gene conversion and repeats

- Majority of genome repetitive sequence
- Provides template for exchange of DNA – network connections
- Maintained by short term selection on new links – hitchhiking homology
- Repetitive landscape conserved and evolves
- Links selected for increase linkage
  - Not the case if no selection