# Biological robustness:

## cd Do TE SLI what do we learn from (mathematical) physics ?

Annick LESNE

Institut des Hautes Études Scientifiques (Bures-sur-Yvette)

**systems epigenomics group** **http:// seg.ihes.fr**

## Functional robustness

robustness differs from stability

$\longrightarrow$ structural vs functional robustness

counter-intuitive role of noise

(statistical laws, stochastic resonance, dynamic flexibility)

Robustness ensuring survival in a changing environment,

defining acceptable perturbations and viability domain.

## Selection

(i) dynamic selection vs (ii) natural selection

(i) persistence between $t$ and $t + \delta t$

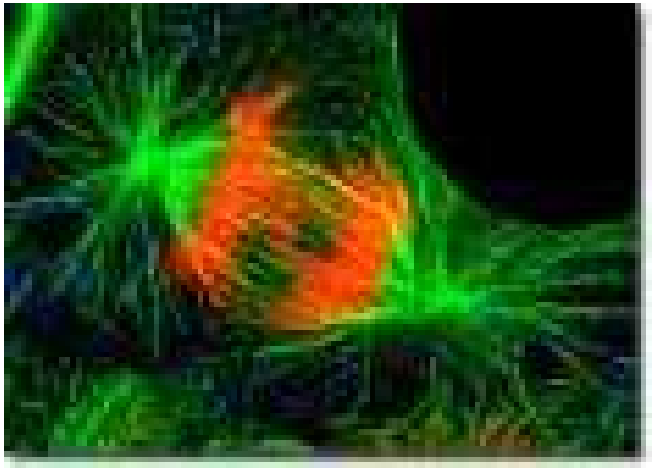
(ii) reproduction with multiplication between $t$ and $t + \delta t$

In living systems: a posteriori "design" through natural selection (achieving adaptation and co-evolution), yielding efficiency and robustness for a range of conditions and perturbations.

"Function" = short curt for a long evolutionary history

(a posteriori optimization criterion : reproduction rate, fitness)

## An exemple: the mitotic splindle



## Robustness and networks

- robustness of network **structure**

(e.g. failures and attacks in scale-free networks)

- robustness of network **dynamics** (redundancy, emergence)
- **functional** robustness (regulatory networks)
- **adaptability** (plasticity)

## Robustness vs adaptability

Balance between **robustness** and **adaptability**

$\longrightarrow$ Nested notions of robustness

Several **scales** (for perturbations, for responses)

Several **layers** (structural, functional, regulatory, adaptive ...)

## Nested notions of robustness

**Deterministic relationship $F(X,Y)=0$, solution $X^*_F(Y)$**

(i) value of the derivative $dX^*_F/dY = -F'_Y/F'_X$ (dynamic stability)

(ii) variations $X^*_{F+\delta F}(Y) - X^*_F(Y)$ (structural stability )

(iii) family $(F_a)_a$ and singularities in $X^*_{F_a}(Y)$ (scenario genericity)

**Stochastic relationship described by a distribution $P(X|Y)$**

(i) width of $P(.|Y)$ at fixed $Y$

(ii) sensitivity of $P(.|Y)$ or its moments with respect to $Y$

(iii) genericity of the relation $Y \to P(.|Y)$ as a whole.

## Conclusions and perspectives

A **context-dependent** notion

Basically, physics teaches us that biological robustness is different

Importance of specifying

— the investigated **feature** (what is expected to be robust?)

— the set of **perturbations**

— the relevant **scales**

Notion of robustness profile (both adaptation and misadaptation)

A whole research direction: network dynamics

(role of topology, local/global, redundancy ...)