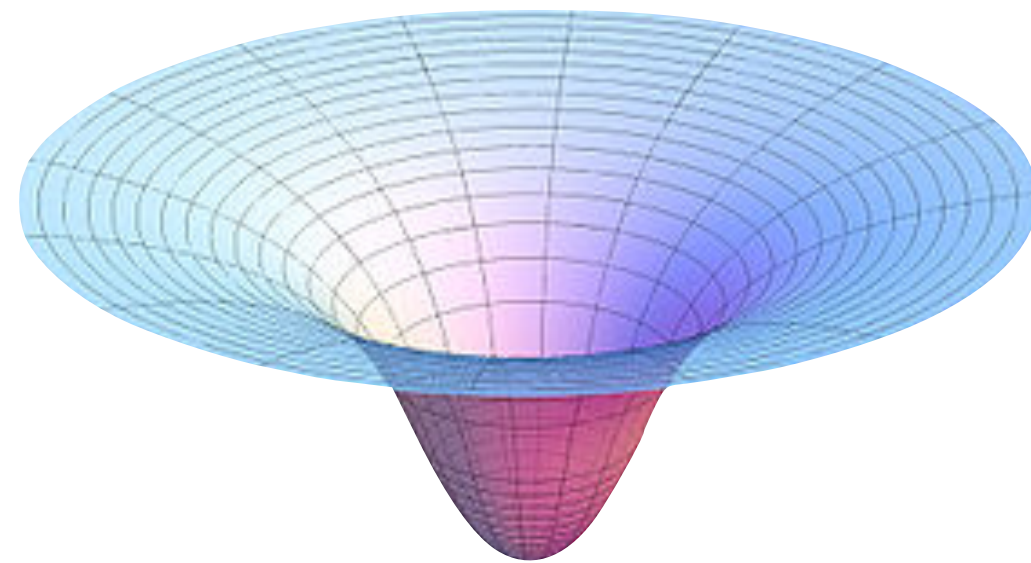# The *Multiple Origins* of Life in Complex Time

DK||SFI

Part 3: The Theory of
The Adaptive Arrow of Time

The Fundamental Theorem of Natural Selection

R.A. Fisher, 1930

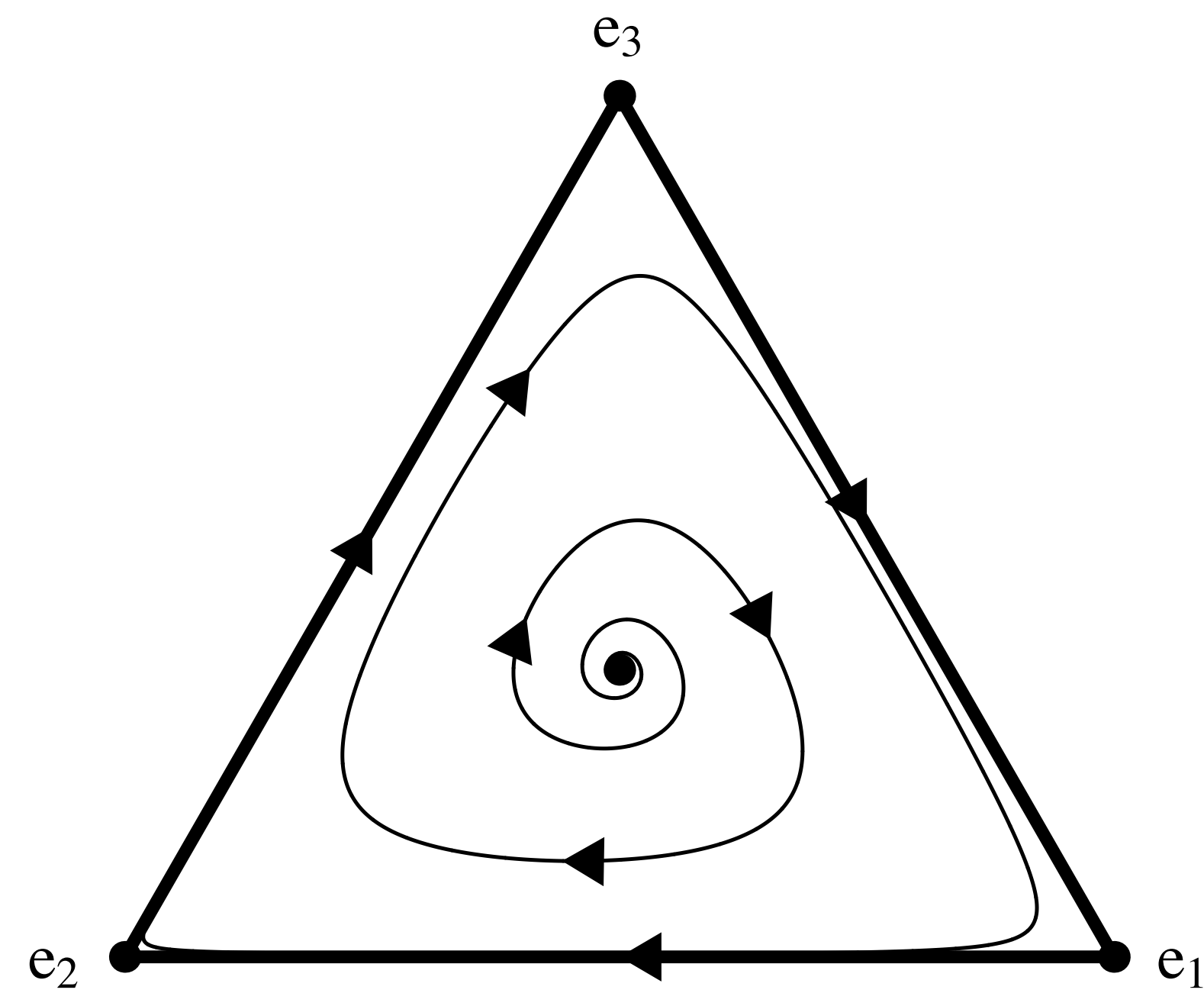$$\frac{dx_i}{dt} = \frac{\partial V}{\partial x_i}$$

the Euclidean gradient vector field on $\mathbb{R}^n$

$$\dot{V}(\mathbf{x}) = \sum_{i=1}^{n} \overbrace{x_i \left(r_i(\mathbf{x}) - \bar{f}(\mathbf{x}) \right)^2}^{\textbf{shashahani gradient}}$$
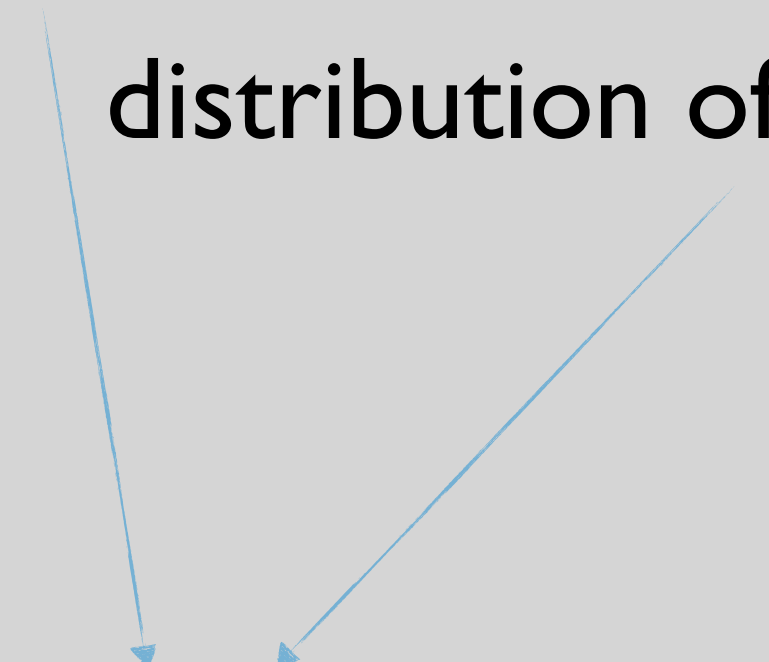
Payoff Matrix

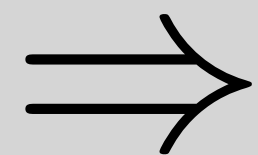|	R	P	S
R	1	0	a
P	a	1	0
S	0	a	1

e_3

e_2 e_1

distribution of phenotypes

distribution of environments

$$D_{KL}(X||Y) = \sum_i x_i \ln\left(\frac{x_i}{y_i}\right) \approx \frac{1}{2}\int x(\partial_\epsilon \ln x)(\partial_\epsilon \ln x)dx$$
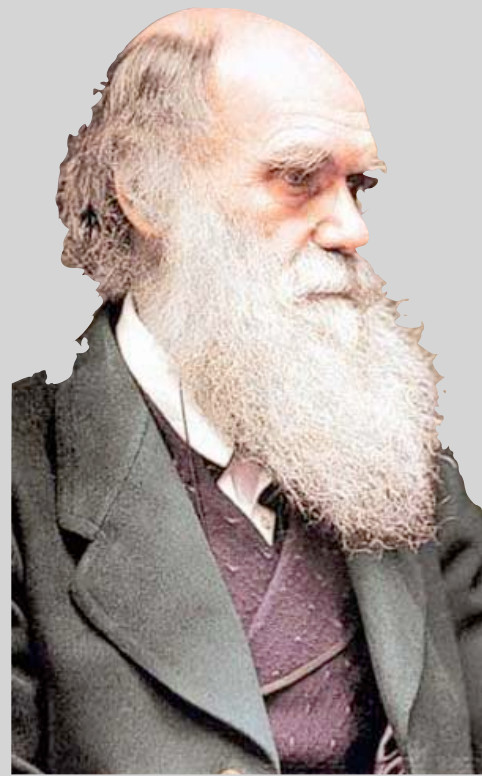
$$D_{KL}(X,Y||XY) = \sum_y p(y) \sum_x p(x|y) \ln \frac{p(x|y)}{p(x)} = I(X;Y)$$

$$I(X;Y) = H(X) + H(Y) - H(X,Y)$$

$$= H(Y) - H(Y|X)$$

$\Rightarrow$

**adaptation is an optimization dynamics
transferring information
from the environment into the agent
- reducing uncertainty about states of the world**

Krakauer & Rockmore - 2016

A scale-invariant, substrate-neutral, stochastic process

$$\frac{dP_i}{dt} = P_i(r_1 - \bar{r})$$

Replication &
competition

Evolution

$$\frac{dP_x}{dt} = qP_x(L_x - \bar{L})$$

Estimating Probabilities

Inference

$$\frac{dx_k}{dt} = \alpha x_k(r_k - \bar{f})$$

Law of effect

Learning