

# EVOLUTION OF PREFERENCES

Mini-course at Bocconi

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# 1 The economics paradigm

- The main paradigm in economics is *Bayesian* and *rationalistic*. Foundations:
  - John von Neumann and Oskar Morgenstern (1944): *Games and Economic Behavior*
  - John Nash (1950): “Non-cooperative games”, Ph D thesis (Princeton University)
  - Leonard Savage (1954): *The Foundations of Statistics*

- Each economic agent's behavior derived from *maximization of some goal function* (utility, profit), under given constraints and information
- The "as if" defence of this paradigm is evolutionary:
  - Milton Friedman (1953): *The Methodology of Positive Economics*
  - Firms that do not take profit-maximizing actions are selected against in the market
  - Is this claim right? Under perfect competition? Under imperfect competition?

## 2 The evolutionary paradigm

- Formulated by *Charles Darwin* and combined with game theory by *John Maynard Smith*
  - Darwin: non-strategic interactions, like *perfect competition* in economics
  - Maynard Smith: strategic interactions, like *imperfect competition* in economics

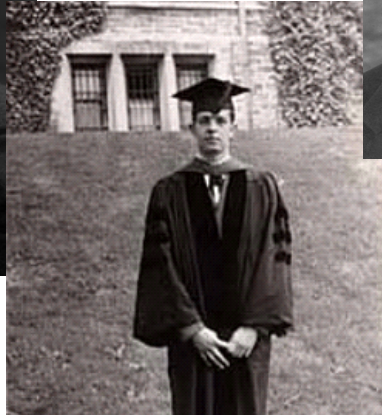
### 3 Three branches of game theory

- *A mathematically formalized theory of strategic interaction*
- Applications abound, in economics, political science, biology, and computer science
- *Non-cooperative, cooperative, and evolutionary game theory*
- John Nash's (1950) Ph D thesis in mathematics at Princeton ("A Beautiful Mind")
- Nash's two interpretations: one rationalistic/individualistic, one evolutionary/population-statistical



## **John Nash**

(born 1928, PhD 1950)



## Citation from Nash's Ph D thesis<sup>∞</sup>

"We shall now take up the "**mass-action**" interpretation of equilibrium points. [...] It is unnecessary to assume that the participants have full knowledge of the total structure of the game, or the ability and inclination to go through any complex reasoning processes. But the participants are supposed to accumulate empirical information on the relative advantages of the various pure strategies at their disposal.

To be more detailed, we assume that there is a population (in the sense of statistics) of participants for each position of the game. Let us also assume that the "average playing" of the game involves  $n$  participants elected at random from the  $n$  populations, and that there is a stable average frequency with which each pure strategy is employed by the "average member" of the appropriate population.

Since there is to be no collaboration between individuals playing in different positions of the game, the probability that a particular  $n$ -tuple of pure strategies will be employed in a playing of the game should be the product of the probabilities indicating the chance of each of the  $n$  pure strategies to be employed in a random playing. [...]

Thus the assumptions we made in this "mass-action" interpretation lead to the conclusion that the mixed strategies representing the average behavior in each of the populations form an **equilibrium point.**"



## 4 Evolutionary game theory

**Evolutionary process = mutation process + selection process**

**Unit of selection:** usually strategies ("strategy evolution"), sometimes goal functions ("preference evolution", "indirect evolution")

Analytical tools for the researcher:

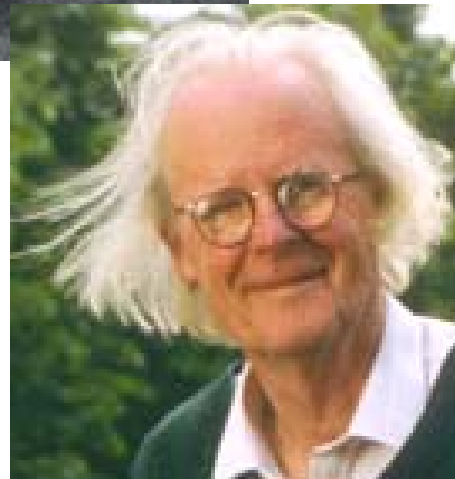
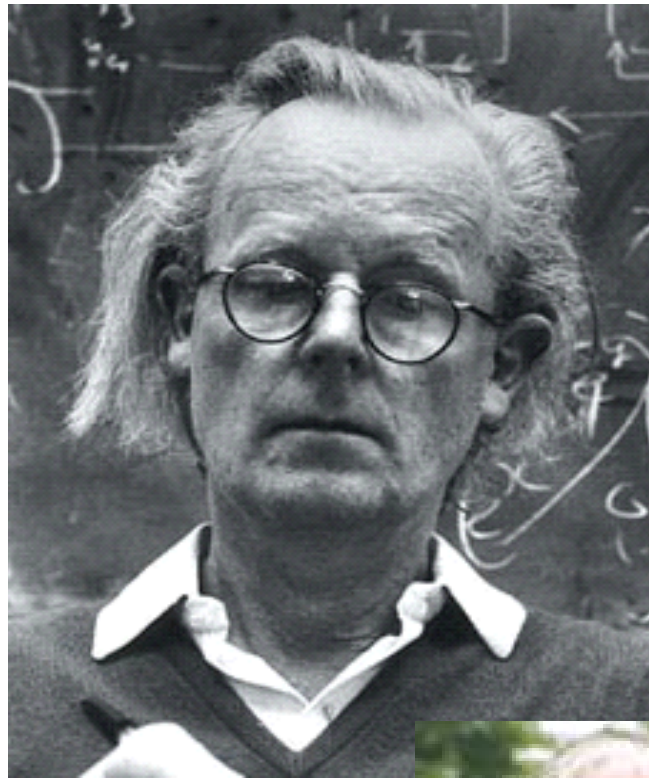
1. **Evolutionary stability:** focus on mutations
2. **Replicator dynamic:** focus on selection
3. **Stochastic stability:** both selection and mutations

## 5 Evolutionarily stable strategies

[Maynard Smith and Price (Nature, 1973)]

Here the unit of selection, the heritable trait, is a *behavior*, a pure or mixed strategy in a finite and symmetric two-player game

- **ESS** = *evolutionarily stable strategy*
  - "ESS"  $\approx$  "a strategy that 'cannot be overturned' once it has become the 'convention' in a population"





## Heuristically

1. A large population of individuals who are recurrently and uniformly randomly matched in pairs to play a finite and symmetric two-player game
2. Initially, all individuals always use the same pure or mixed strategy,  $x$ , the *incumbent* (pure or mixed) strategy
3. Suddenly, a small population share  $\varepsilon$  switch to another pure or mixed strategy,  $y$ , the *mutant* (pure or mixed) strategy

4. If the residents/incumbents on average *do better* (in material payoffs, fitness) than the mutants, then  $x$  is *evolutionarily stable against  $y$*
5.  $x$  is *evolutionarily stable* if it is evolutionarily stable against *all  $y \neq x$*

## Quasi-formally

A (pure or mixed) strategy  $x$  is an ESS (as defined in Maynard Smith & Price 1973) if

(i)  $x$  is a best reply to itself, and

(ii)  $x$  is a better reply to all other best replies to  $x$  (than they are to themselves)

$\Rightarrow (x, x)$  must constitute a Nash equilibrium, and, in addition, "fight back"  
other best replies

## Formally

- Domain of analysis: finite and symmetric two-player games
- Let  $S = \{1, 2, \dots, m\}$  be the set of pure strategies in the game
- Let  $X = \Delta(S) = \left\{x \in \mathbb{R}_+^m : \sum_{h=1}^m x_h = 1\right\}$  be the (unit simplex) of mixed strategies  $x$
- For any  $x, y \in X$ , let  $\pi(x, y) \in \mathbb{R}$  be the (material) payoff to a player who uses strategy  $x \in X$  when the other party uses  $y \in X$ 
  - Note:  $\pi$  is a continuous (polynomial) bi-linear function (linear in  $x$ , for any given  $y$ , and linear in  $y$ , for any given  $x$ )



The following definition can be shown to be equivalent to the definition in Maynard Smith & Price (1973):

**Definition 5.1** *A strategy  $x \in X$  is evolutionarily stable if for every strategy  $y \neq x$  there exists an  $\bar{\varepsilon}_y > 0$  such that for all  $\varepsilon \in (0, \bar{\varepsilon}_y)$ :*

$$\pi(x, (1 - \varepsilon)x + \varepsilon y) > \pi(y, (1 - \varepsilon)x + \varepsilon y)$$

- The mixed strategy  $z = (1 - \varepsilon)x + \varepsilon y \in X$  is called the post-entry mixture.

## 5.1 Examples

### 5.1.1 Prisoner's dilemma

- To cooperate or defect?
- To fish aggressively in the common pool, or fish modestly?

	<i>C</i>	<i>D</i>
<i>C</i>	3, 3	0, 4
<i>D</i>	4, 0	2, 2

- One ESS: **play D**. Cooperation is ruled out

## 5.1.2 Coordination game

- To meet at the good restaurant or at the bad restaurant?
- To stick to the more efficient industrial standard or to the less efficient?

	<i>A</i>	<i>B</i>
<i>A</i>	2, 2	0, 0
<i>B</i>	0, 0	1, 1

- Two ESSs: **play A**, or, alternatively, **play B**. The inefficient industrial standard is *not* ruled out (but the mixed Nash-equilibrium strategy is ruled out)

### 5.1.3 Hawk-dove game

- Start-up business with two partners
- Pairs of researchers or workers assigned a common task

To *work* or *shirk*?

	<i>W</i>	<i>S</i>
<i>W</i>	3, 3	0, 4
<i>S</i>	4, 0	-1, -1

What will happen?

A unique strategy that is a best reply to itself: randomize 50/50 between "work" and "shirk"  $x^* = (1/2, 1/2)$

This is an ESS if it is also a better reply to *all other* (pure or mixed) strategies than they are to themselves

Can be verified that this is the case, by way of calculus

- One ESS: **randomize 50/50** between *work* and *shirk*

We now proceed to apply this framework to

1. Evolutionary stability of altruism between siblings who interact pairwise and know each other
  
2. Evolutionary stability of strategies, preferences and moral values under complete and incomplete information
  - (a) in symmetric  $n$ -player games
  
  - (b) under random matching without assuming uniformity

We conclude by briefly discussing implications for analysis and policy in economics and political science