Signals:
Evolution, Learning, and Convention

Brian Skyrms

"Two savages, who had never been taught to speak, but had been brought up remote from the societies of men, would naturally begin to form a language by which they would endeavor to make their mutual wants intelligible to each other…"

Adam Smith

Considerations Concerning the First Formation of Languages

1761

“In that gathering of men, at a time when utterance of sound was purely individual, from daily habits they fixed on articulate words just as they happened to come; then, from indicating by name things in common use, the result was that in this chance way they began to talk, and thus originated conversation with one another.”

Vitruvius

The Ten Books of Architecture Bk2, Ch1

27 BC

Democritus Laughing, by Hendrick ter Brugghen, 1628

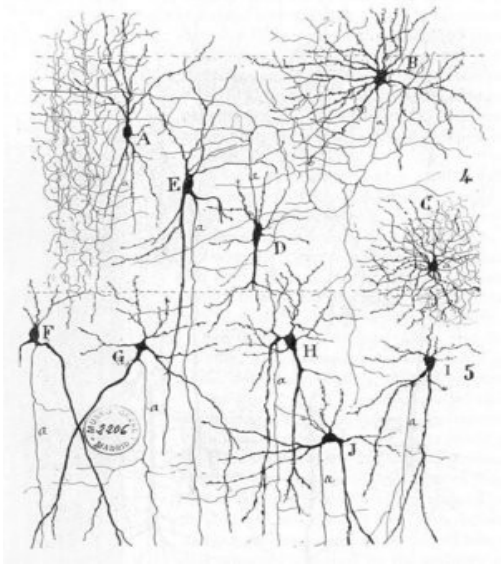
Democritus

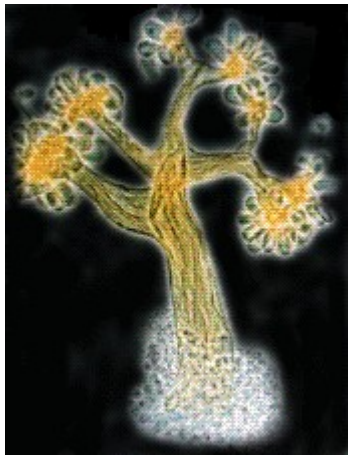
The Laughing Philosopher

400BC

Proclus states that Pythagoras and Epicurus agree with Cratylus, but Democritus and Aristotle agree with Hermogenes, the former that names arise by nature, the latter that they arise by chance.

Signals in Nature





After Darwin, innate signals also require a dynamic explanation.

Scientific Philosophy

Game Theory

Information Theory

Evolutionary Dynamics

Stochastic Models of Learning

Sender-Receiver Games

David Lewis *Convention* 1969

States, Signals, Acts

SENDER	RECEIVER
State => Signal	Signal => Act

Common Interest

Signaling System Equilibria

Information in Signals

The amount that probabilities change if that is the signal.

(Kullback-Leibler distance)

2 Kinds

About the State

About the Act

Both maximal in a Signaling System, but also …

Evolution

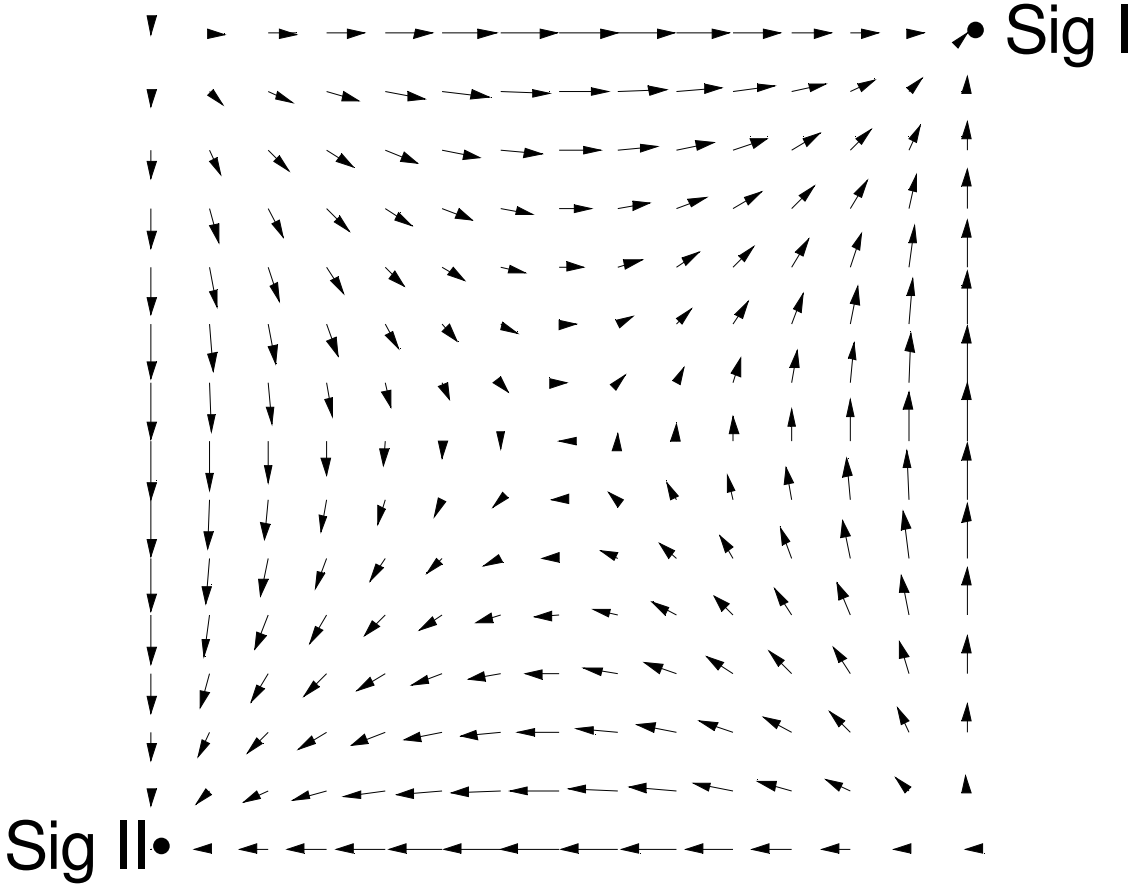
Replicator Dynamics

Differential reproduction in a large popula

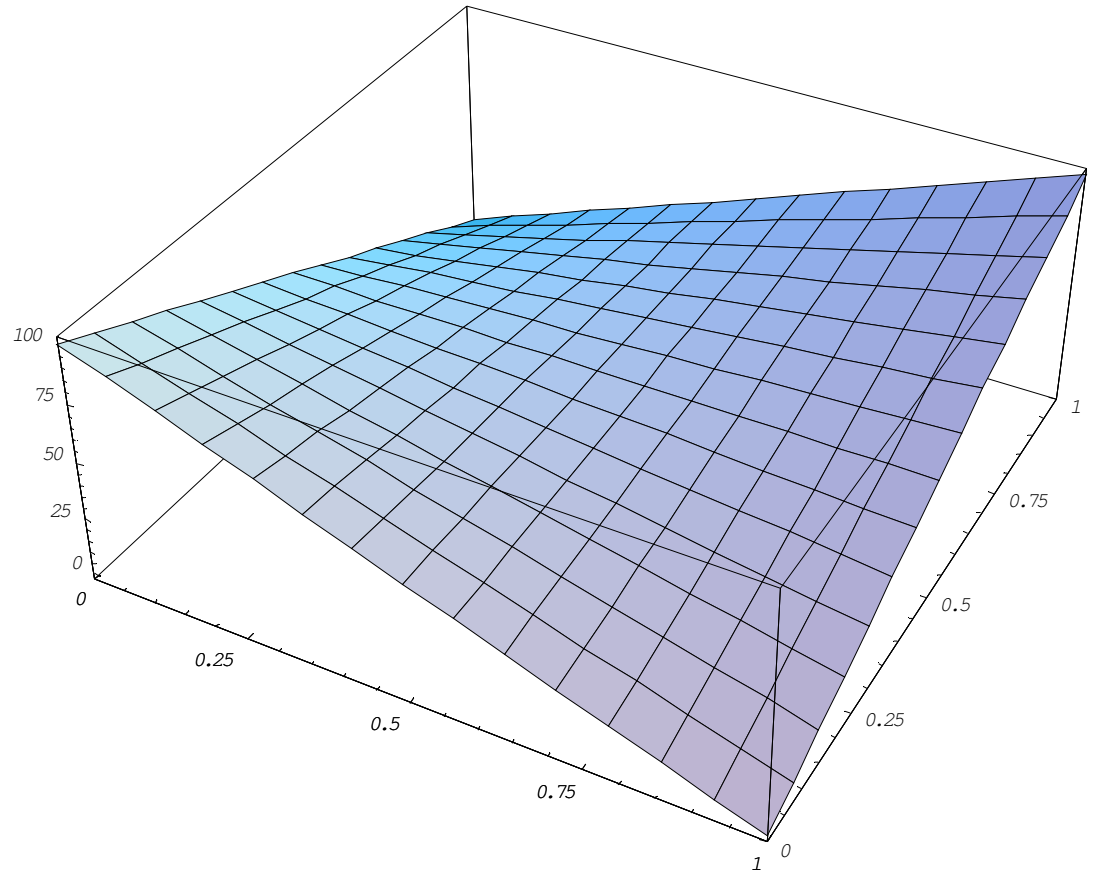
2 populations: Senders; Receivers

1 population: roles

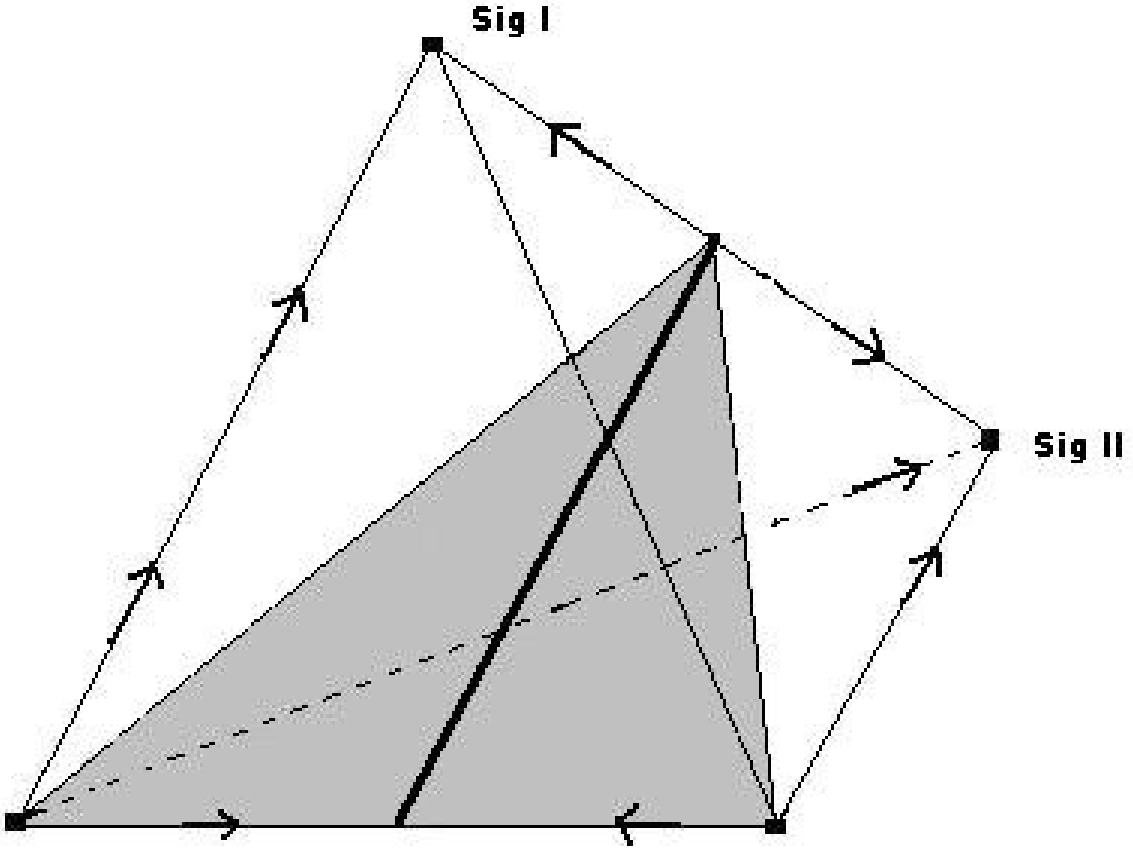
Evolution of Signaling: 2 populations



Evolution of Signaling I: Average Payoff



Evolution of Signaling: 1 population



Generalizations

Include all possible strategies

States Unequal Probabilities

N states, N signals, N acts

Learning

Herrnstein's Matching Law

2 Armed Bandit -- Beggs (2005)

Reinforcing Strategies

SENDER

State => Signal

RECEIVER

Signal => Act

Simulations

A simple example with a proof.

Reinforcing Actions

SENDER	RECEIVER
Urn for State 1	Urn for Signal 1
Urn for State 2	Urn for Signal 2

Forthcoming proof : Argiento, et al

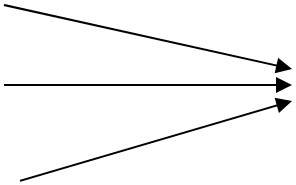
Generalization I

Different sizes of State, Signal, and Act Spaces

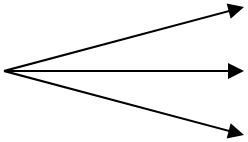
Too Many Signals

Too Few Signals

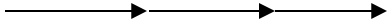
Generalization II
Signaling Networks



Many Senders



Many Receivers



Chains