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
The Laughing Philosopher
400 BC

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.
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**
State $\Rightarrow$ Signal

**RECEIVER**
Signal $\Rightarrow$ 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 population

2 populations: Senders; Receivers

1 population: roles
Evolution of Signaling: 2 populations

Sig I

Sig II
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**
- Urn for State 1
- Urn for State 2

**RECEIVER**
- Urn for Signal 1
- 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