The Selfish Gene and The Evolution of Cooperation

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January 11, 2013

My goal for this workshop

- Identify an interesting problem to work on

Questions I hope we address in this workshop

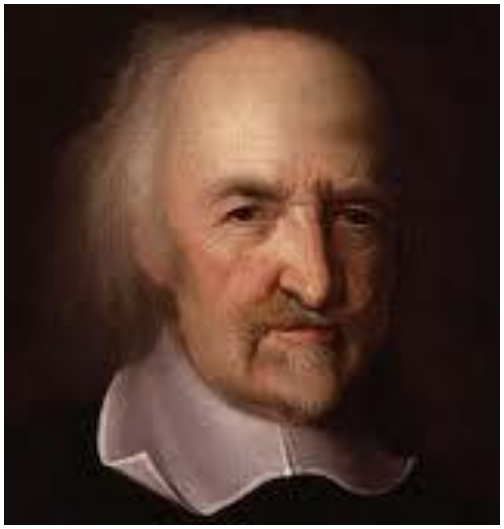
- **Why are we selfish?**
- **Why do we co-operate?**
- **Is cooperation an emergent phenomenon,which can be influenced/guided?**
- **Relevance: The answers to these questions connect biology, sociology, anthropology, morality/religion/ethics, behavioral psychology, business practices and politics !**

Relevance to Religion/Morality/Ethics

- Is Religion necessary for Moral behavior?
- Or does cooperation emerge naturally in a world of egotists without central authority?

Thomas Hobbes (1588-1679)

- Nature is dominated by selfish individuals who compete on ruthless terms
- "life is solitary, poor, nasty, brutish and short."
- Cooperation cannot emerge without a central authority because:
- A strong government is necessary.



Definitions

- Altruism: behavior which increase another entity's welfare at the expense of ones own
- Selfishness: behavior which increase an entity's welfare at the expense of all others it encounters.
- Welfare = "Chance of Survival" or "Chance for Reproductive Success"

Meerkats (Kalahari) Share Baby sitting

Colobus Monkeys sharing food

Budgies sharing fruit

We can learn from observation

- If we are told of a man who lived and prospered amongst gangsters, we would infer that he is: tough, ruthless, with a quick trigger finger & the ability to attract loyal friends

- We can deduce a woman/man/animal's nature from the conditions under which she/he survived and prospered

“The Selfish Gene” al la Dawkins

- Like successful New York gangsters, our genes have survived for millions of years by competing with each other
- We are **“Survival Machines”** created by genes
- The pre-eminent quality to expect from the genes is ruthless selfishness

Examples of Selfishness

- Black-headed gulls eat chicks from neighboring nests when parents are away
- Praying Mantis female eats male after mating
- Penguins in the Antarctic push other penguins off ice to test if seals are in the water before jumping in to feed.

What "The Selfish Gene" DOES NOT TELL US

- This does not mean our morality is, or should be, based on what genes do.
- Genetics and Evolutionary theory do not say how humans ought to behave.
- **"One should distinguish between what IS the case, from what we wish to believe SHOULD be the case."**
- **Morality is merely one choice among possible of behavioral phenotyes.**

Examples of Altruism

- When worker bees sting honey robbers, vital organs are torn out and the bees die.

- Ground nesting birds perform a “distraction display” when a predator approaches – to lure it away from its nestlings

Mimicry/deceit

leaf mimic frog

Dead leaf Mantis

Angler fish and lure

Leaf mimic fish

Bee and Bee Orchid

Eucalyptus Leaf Insect

"*Group Altruism*" The genesis of a dogma (Fallacy?)

- Animals spend time and energy in reproduction and nurture
- This is wrongly labeled "Perpetuation of the Species" – which is the consequence & not the motivation for reproduction
- A slight (false) stretch of logic then deduces that the "function" of reproduction is "to" perpetuate the species
- The final error is to conclude that animals "behave" so as to "perpetuate the species"

Rebuttal (game theory has a proof)

- In a group of altruists, there is always a dissenting minority who will refuse to make sacrifices.
- This minority is likely to have better reproductive success.
- Their progeny will inherit “selfish genes”
- After several generations of natural selection, these “rebels” will out-compete the altruists.

Why the dogma persists

- In tune with political and moral ideas that make us honor and admire those who put the welfare of others before their own

- However, we are altruistic within a group (family, clan, language/national group) and selfish between groups. The latter is the voice of the “selfish gene”.

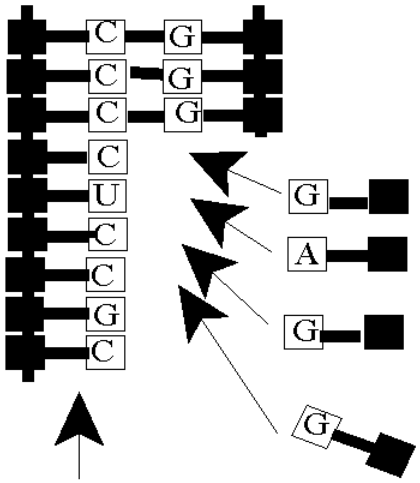
Possible underlying causes of cooperation/altruism

- Gene Survival
  - Kinship recognition
  - Reciprocal benefit
- Expectation/certainty of Reward/Punishment
- Nurture
- Culture (language, heritage, religion, tradition)
- Imprinting/education

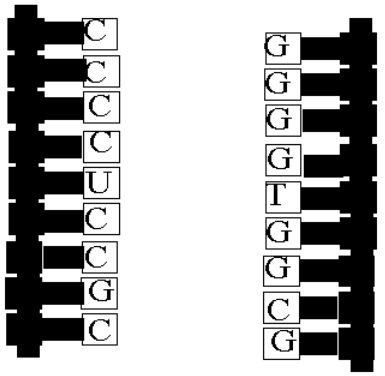
Cooperation as an Emergent Phenomenon
Replicators and the Origin of Life

- The original life form was most likely an RNA molecule (**a replicator**) which could copy itself.
- Over time, because of **mutations**, many types and numbers of replicators evolved.
- **Finite resources and natural selection** led to a **variety of replicator types**
- Fitness depended on longevity, fecundity, accuracy of replication and reproductive success

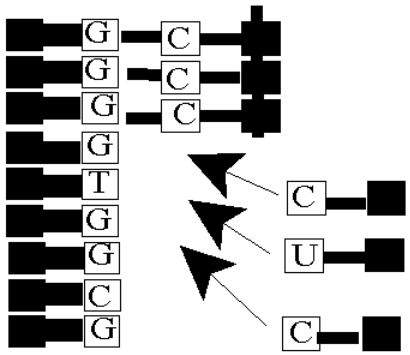
Conceptual Model of RNA Self Replication



1) Initial Growth

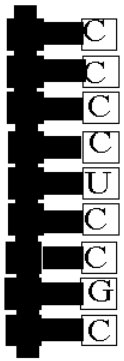


2) Complementary Strands Separate



3) Growth Second Round

4) Complementary Strands Separate



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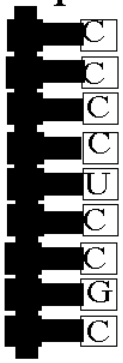

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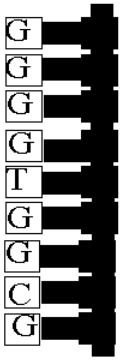


Free to make more copies

PROTOTYPE OF A REPLICATOR

Primeval Soup

- Consisted of stable varieties of replicator molecules.
  - Were they “alive”?
  - What does that mean?
- They “competed” for survival via natural selection.
- Almost certainly there were predator replicators
- So some built enclosures (cell walls) to protect themselves

Evolution of Complexity

- Replicator containing cells became complex
- Over time, they evolved methods to store (DNA), retrieve (Polymerase, Ribosomes) and process (signaling pathways) information to perpetuate their replicators
- They invented ways of increasing stability and eliminating rivals
- They built “survival machines” (us) to live in.

The main unit of control is a gene – and genes are multi-functional

- Sets of genes regulate different functions
- This program is set soon after fertilization and is tissue specific
- It is regulated and can be globally modified
- It is inherited when cells replicate (mitosis)
- Some genes are “imprinted”
- There are even “interference genes” and “killer genes”

What are the gene's priorities?

- Highest priorities: Survival and Reproduction

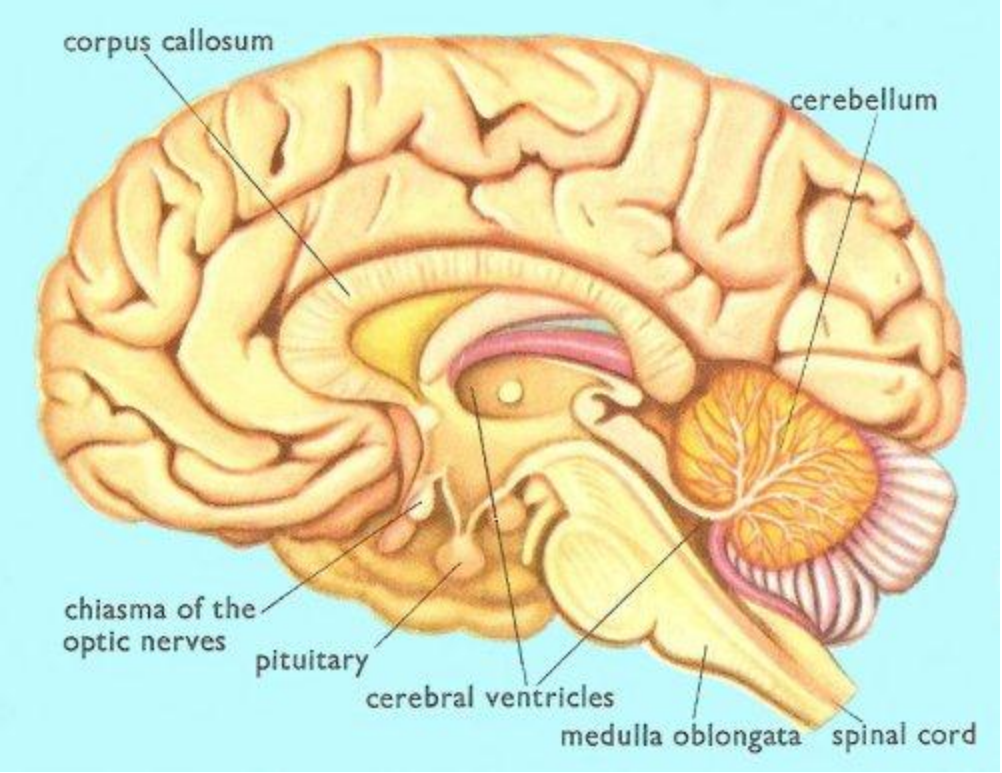
- Genes cooperate to achieve these ends
  - Find and catch/gather food
  - Avoid being caught and eaten
  - Avoid disease and accidents
  - Protect themselves from the environment
  - Survive !

Survival Machines (SMs) evolved "brains" = information processing "simulators"

- SMs who learn by "Trial and Error" get hurt.
- SMs who process sensory data and "simulate" the world anticipate danger and are fitter.
- "Simulating Brains" took charge of the day to day running of the SMs.

Brains and Consciousness

"Consciousness" may have appeared when the Brain's "simulation" of the world included a model of itself.

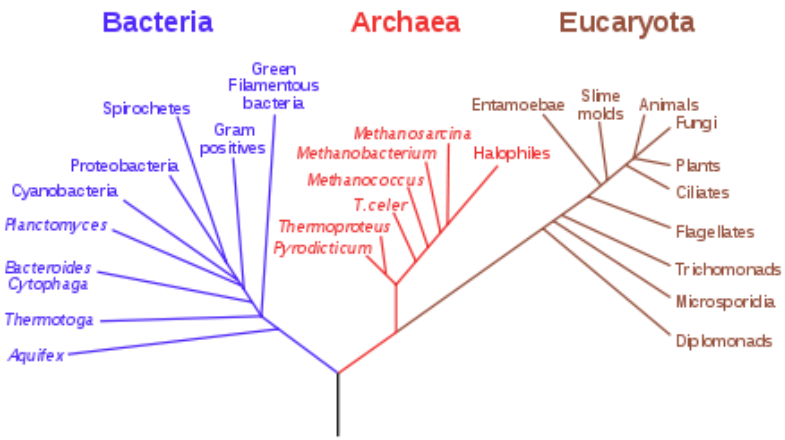


The Tree of Life

- Over 4,000,000,000 years, Survival Machines (SMs) became elaborate and diverse!

- Replicators became immortal, swarming in huge colonies, safe inside gigantic lumbering robots (us), manipulating them by remote control !

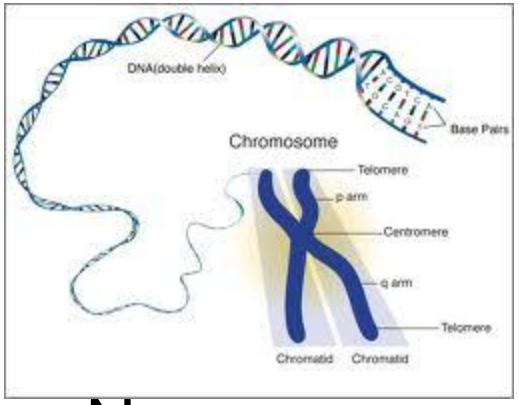
Phylogenetic Tree of Life

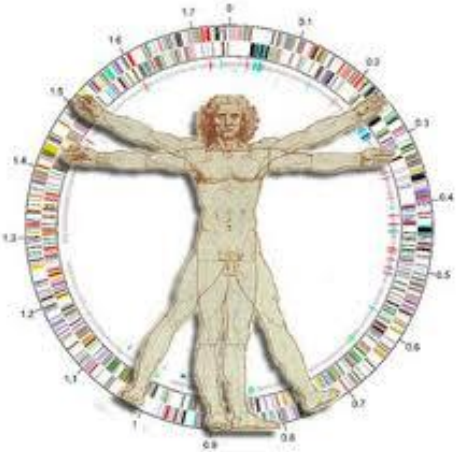


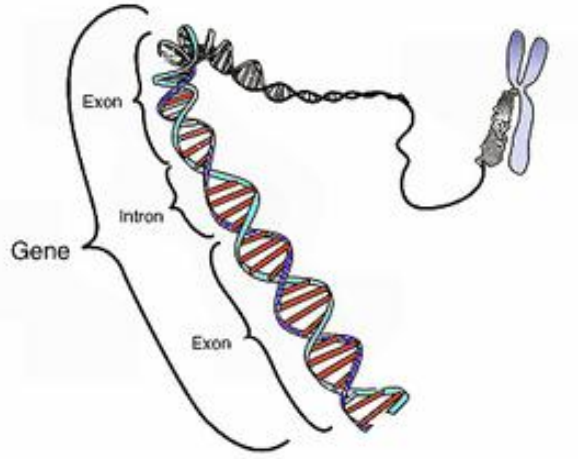
How/Why SMs communicate

- Communication = When SMs can influence behavior of other SMs
  - Language, literature, culture, & institutions to influence other human beings
  - Bird song, cricket's chirp, firefly's glow
  - Bees dance in the dark to communicate
  - babies cry to attract attention
  - Peacock tails, blushing, bilateral symmetry signal strength and health

Once there is “free will”, is the gene’s tyranny over?







- No, genes remain primary policy makers. Brains are only executives
- As brains took over control, the genes gave them a single overall policy instruction
- DO WHATEVER YOU CAN TO KEEP US ALIVE
- The Soma is the “Instrument”, the Germ Line is the “Treasure.”

How genes control SMs

- Honey bee grubs have a disease called foul brood
- In Hygenic strains, workers find infected grubs, uncap cells & throw grubs out. Susceptible strains don't do this
- Rothenbuhler crossed these two strains and got three types: hygenic, non-hygenic and a type that uncapped the cells but did not throw out grubs.
- **When he uncapped the cells himself, half the non-hygenic bee crosses threw the grubs out !**
- **Conclusion: There are two "recessive" genes: one for uncapping and one for throwing grubs out.**

"Kin Selection" & cooperation: SMs recognize "similar" SMs

- Similar = "SMs likely to carry the same genes"
- Kinship Coefficient = $(½)^g$, g = generation distance
  - Identical twins: 1, Siblings: ½, parent/child : ½, Uncles/aunts ¼, first or second cousins: 1/8 or 1/16,
- Parental care is "kin altruism". We should care as much for a baby sister/brother as a child.
- **Is "Kin Selection" effectively "Group Selection"? Or is it all semantics?**

Kinship math

- Suppose I find 8 fruits each of value 6
- But I can only eat three of them.
  - Should I eat 3 and keep quiet (and maybe eat them later)
  - Or should I eat two and give 2 each to : 1 Brother, 1 Cousin and one stranger (kinship 1/2, 1/8 and 0)
- Score if I eat three = 6 x 3 = 18
- Score if I share=12x1+12x1/2+12x1/8=19 ½
- ***SOMETIMES*** **SHARING IS BETTER (has higher payoff) !**

But we don't really do these calculations !

- Just as we do not calculate the trajectory of a ball before we catch it.
- Our brains automatically make such decisions based on
  - Past experience
  - Expectation of future reward (reciprocal altruism)
  - Physical & Chemical cues (instinctive understanding of relatedness)
  - Chance to replicate genes
  - Fear, prejudice, self delusion, brainwashing ….

Why Game Theory?

- It is just a framework to organize ideas and interpret data.

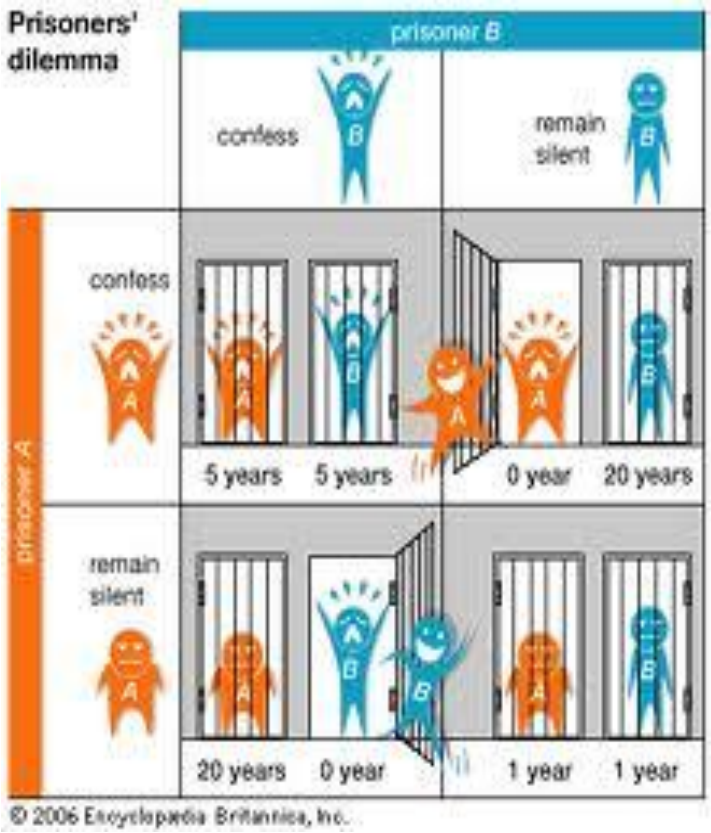
Some Game Theory Applications

- **Price war between stores** (both have incentive to cut prices to attract customers – but if both cut prices, both lose)
- **Two lions sharing a kill** (both have an incentive not to share, but if they fight, both get hurt)
- **Trade barriers between nations** (lowering barriers improves trade, but if only one does it, the other wins – so barriers tend to stay)

Prisoner's Dilemma

1950, Dresher and Flood (RAND Corporation)

- Two prisoners are asked to confess
- If both confess, they go to jail for 5 years (payoff = 1)
- If both don't confess, they get a light sentence (payoff = 3)
- If one confesses, he goes free (payoff = 5), but the other gets a heavy sentence (payoff = 0)



Prisoner's Dilemma payoff matrix

COLIN → / ROSE ↓	A Don't confess	B Confess
A Don't confess	(3, 3)	(0,5)
B Confess	(5,0)	(1 ,1)

Optimum Strategy for Rose is B

(Better choice regardless of what Colin does)

ROSE \ COLIN →	A Don't confess	B Confess
A Don't confess	3	0
B Confess	5	1

Optimum Strategy for Colin is also B

(Better choice regardless of what Rose does)

COLIN → / ROSE ↓	A Don't confess	B Confess
A Don't confess	3	5
B Confess	0	1

But this is bad for both. They would do better by cooperating (both choosing A)

COLIN → / ROSE ↓	A Don't confess	B Confess
A Don't confess	(3, 3)	(0,5)
B Confess	(5,0)	(1 ,1)

- RATIONAL, SELFISH BEHAVIOR OFTEN GIVES LOWER PAYOFF
- SOMETIMES IT IS BETTER TO COOPERATE

Generalized Prisoner's Dilemma

- T > R > P > S (BB is Stable because T>R, P>S)
- R>(S+T)/2 (AA is Optimal :better than AB, BA)

ROSE ↓ / COLIN →	A Don't confess	B Confess
A Don't confess	R = Reward for cooperation (R, R)	T = Temptation S = Suckers payoff (S, T)
B Confess	S = Suckers payoff T = Temptation (T,S)	P = Punishment for mutual defection (P,P)

Iterated Prisoner's dilemma

- If the number of games is finite and known, then both will choose BB
- But if the number of games is uncertain, things change
- If p = probability to play one more game, AA is stable if $p > (T-R)/(T-P) = ½$ (for our choice of parameters)
- IF END OF PLAY IS UNCERTAIN, COOPERTION IS THE BEST STRATEGY

$T>R>P>S$, $R>(T+S)/2$

(R,R)	(S,T)
(T,S)	(P,P)

What happens in Practice?

- **1984, Robert Axelrod**: 14 programs played Prisoner's dilemma 200 times against each other.
- **Winning Program was "TIT FOR TAT"**
  - Start by choosing A
  - In each round, choose whatever the opponent chose in the previous round
- **Repeating the contest with 62 programs gave same result, even though some were designed to do well against "TIT FOR TAT."**

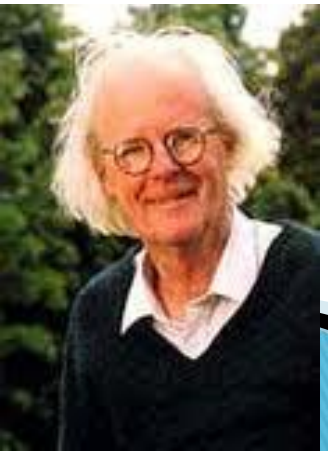
Properties of Top Programs

- **Nice**: Starts by cooperating, never defects first **(friendly)**
- **Retaliatory:** Punishes defection immediately **(strong)**
- **Forgiving:** Willing to cooperate again **(kind)**
- **Clear:** Pattern of play is consistent and easy to predict **(trustworthy)**

Biology and Evolutionarily Stable Strategies (ESS)

Player 2 → / Player 1 ↓	Hawk	Dove
Hawk	(-25,-25)	(50,0)
Dove	(0,50)	(15,15)

- John Maynard Smith and G. R. Price (1973)
- Resource worth 50
- Hawks fight
- Doves posture & give in



- HxH: Injury cost = -100
- DxH or HxD: H wins
- DxD: Wasted time cost = -20

Player 2 / Player 1	Hawk	Dove
Hawk	(−25,−25)	(50,0)
Dove	(0,50)	(15,15)

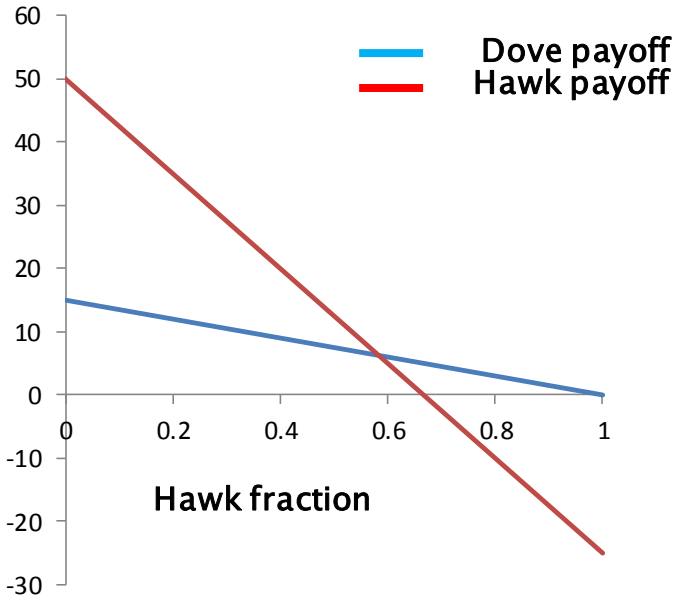
Pure strategies

All Doves, unstable to invasion by Hawks

All Hawks, unstable to invasion by Doves (0 points)

Evolutionarily Stable Strategy (ESS):

BE A HAWK 7 OUT OF 12 TIMES, ELSE BE A DOVE



Bullies overpower Doves

Player 2 Player 1 scores:	Hawk	Dove	Bully
Hawk	-25	50	50
Dove	0	15	0
Bully	0	50	25

- Bully Strategy: Fight if opponent does not fight back. Else run away.
- Bullies dominate Doves
- Doves die out.

BUT ONE CAN BE A RETALIATOR:

Retaliator Strategy: Behave like a Dove. However, if persistently attacked, fight back with ALL YOUR STRENGTH.

How to deal with Bullies

Player 2 Player 1	Hawk	Dove	Bully	Retaliator
Hawk	-25	50	50	-25
Dove	0	15	0	15
Bully	0	50	25	0
Retaliator	-25	15	50	15

100% Retaliators is an ESS.

Doves + Retaliators (Doves < 30%) is also an ESS

Posturing works only if you can fight when provoked

Bourgeois

Player 2 / Player 1	Hawk	Dove	Bully	Retaliator	Bourgois
Hawk	-25	50	50	-25	12.5
Dove	0	15	0	15	7.5
Bully	0	50	25	0	25
Retaliator	-25	15	50	15	-5
Bourgois	-12.5	32.5	25	-5	25

Bourgois Strategy: Be a hawk in your own territory, a dove in someone else's territory. Bourgois Payoff = ½ (Hawk+Dove)

ESS: Retaliators with some doves coexisting, Bourgois with some Bullies coexisting

Colin Rose	A	B
A	(−3,3)	(0,0)
B	(−1,1)	(4,−4)

Zero Sum Game

If both play simultaneously,
Optimum: Rose : (5/8 A, 3/8 B) , $V_{opt}(R) = 3/2$
Colin : (1/2 A, 1/2 B) , $V_{opt}(C) = -3/2$

But if they play successively, First player loses
(i.e. first player always has $V < V_{opt}$)

Colin Rose	A	B
A	(3,3)	(2,4)
B	(4,2)	(1,1)

Chicken

First player chooses B and wins most desired outcome because second will choose A

Colin Rose	A	B
A	(2,3)	(4,1)
B	(1,2)	(3,4)

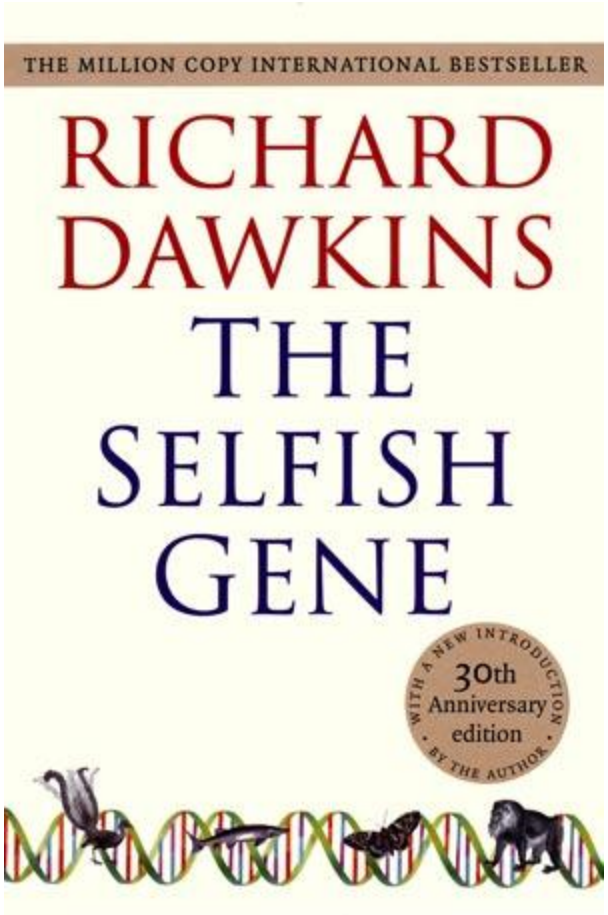
Mixed

Rose A dominates Rose B

If simultaneous, then AA is equilibrium

But if Colin plays first, BB is outcome

Both players prefer Rose to move first



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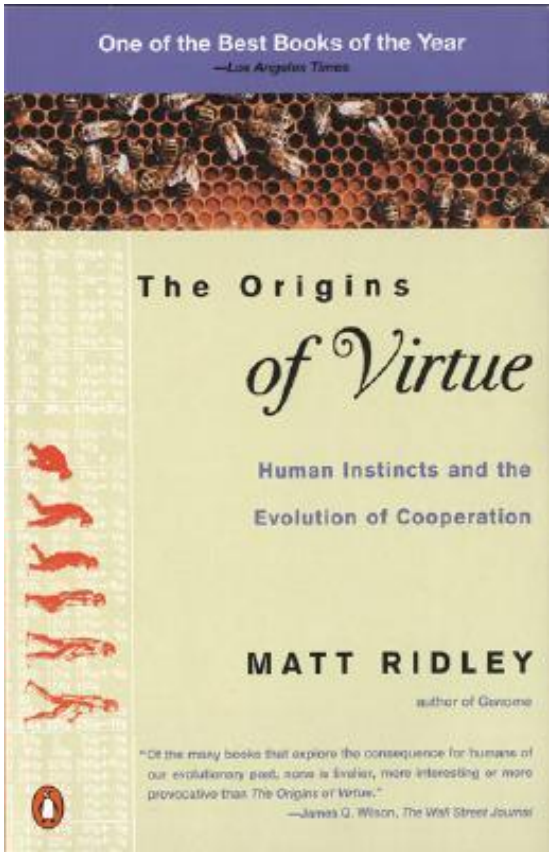
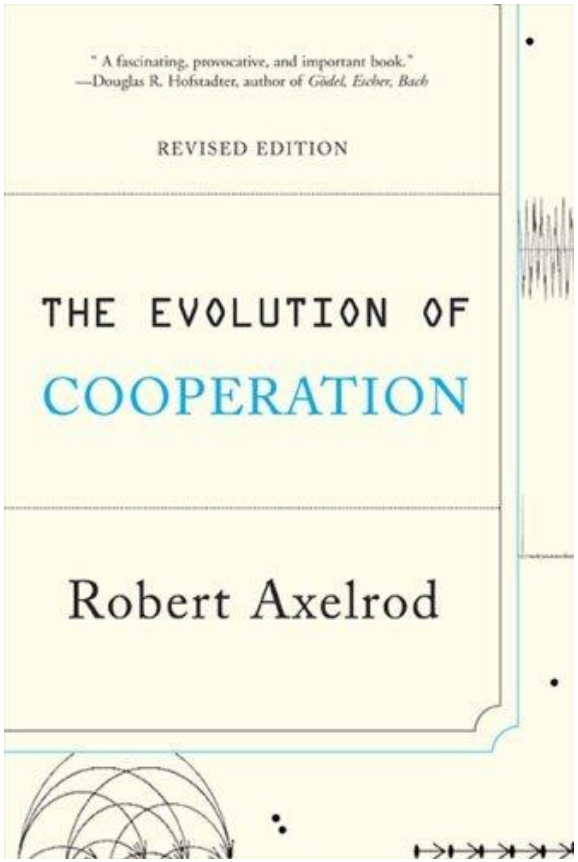
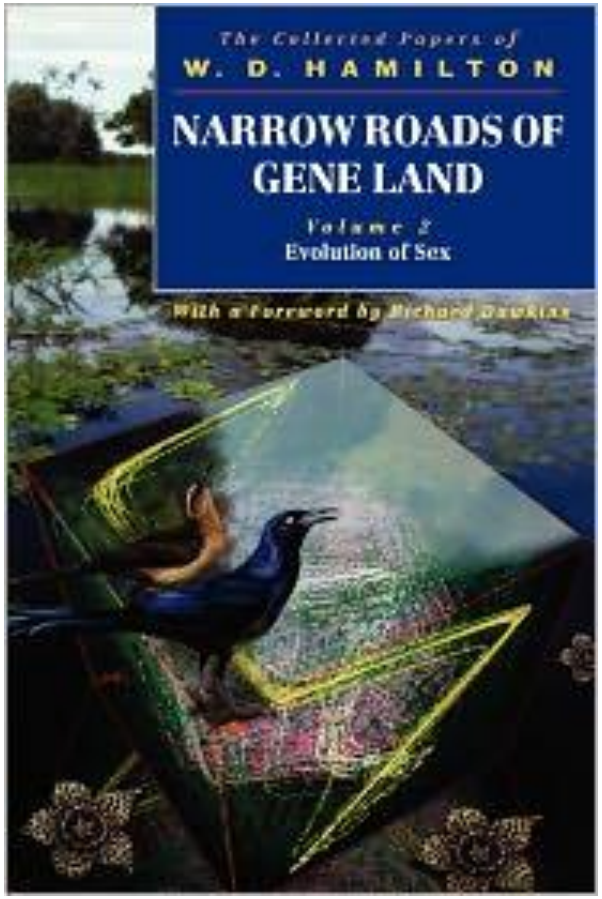


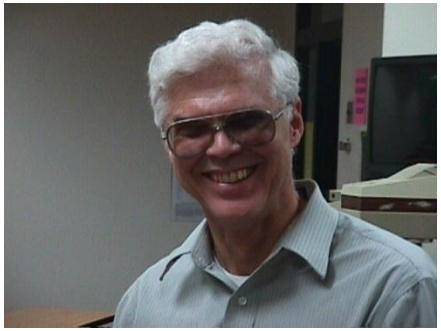
1958 –

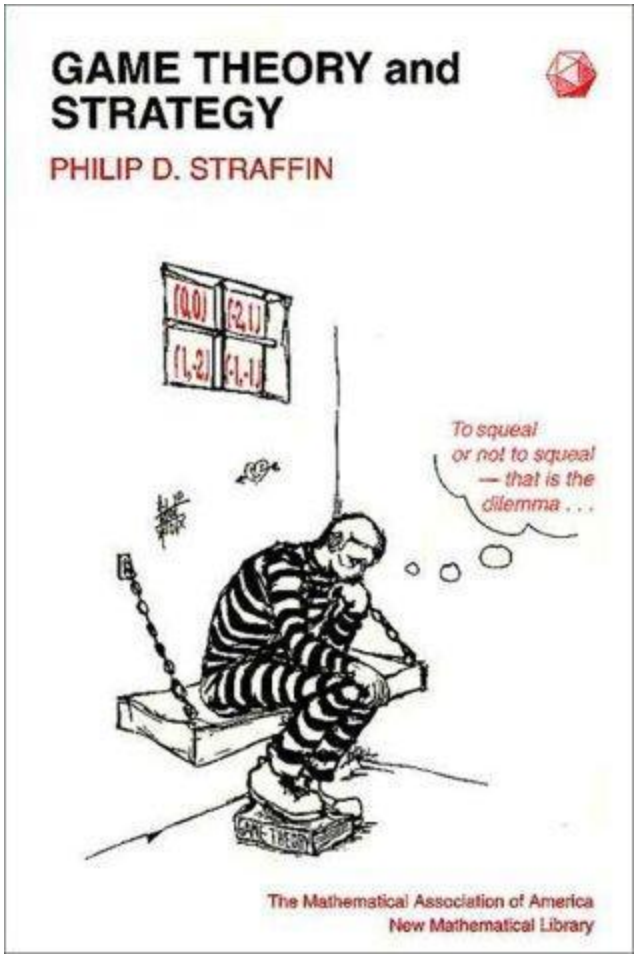


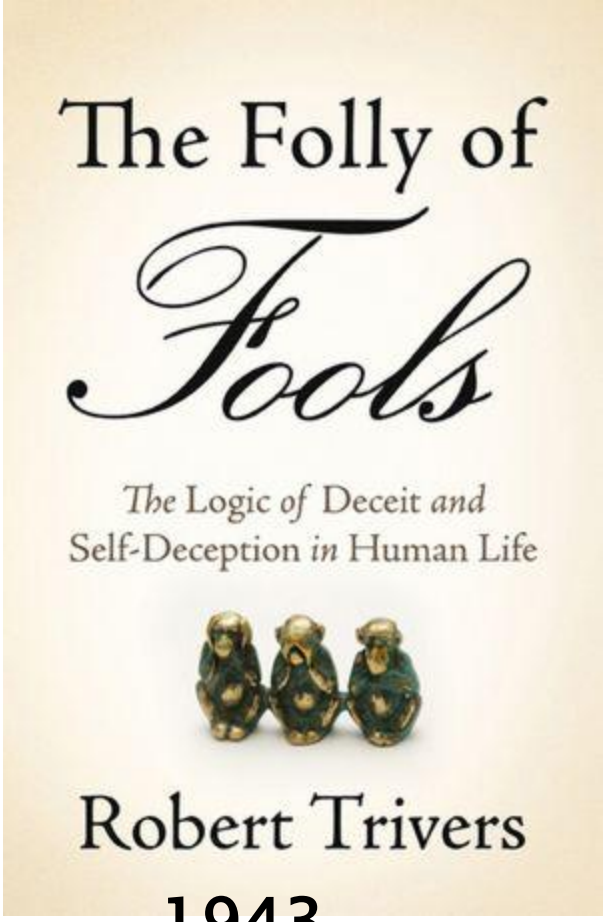
1943 –


The Collected Papers of
W. D. HAMILTON
NARROW ROADS OF GENE LAND
Volume 2
Evolution of Sex
With a Foreword by Richard Dawkins

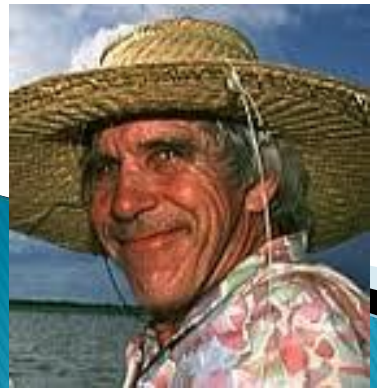
1936 –

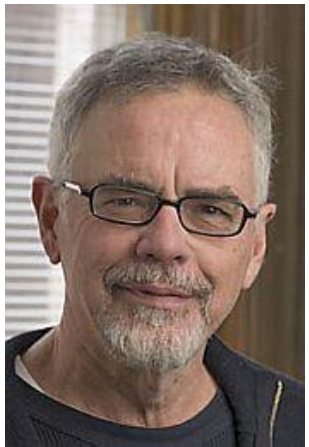



GAME THEORY and STRATEGY
PHILIP D. STRAFFIN
(0,0) (2,1) (1,2) (1,1)
To squeal or not to squeal — that is the dilemma . . .
The Mathematical Association of America
New Mathematical Library


The Folly of Fools
The Logic of Deceit and Self-Deception in Human Life
Robert Trivers

1943 –





THANK YOU !