Evolution of altruism and cheating

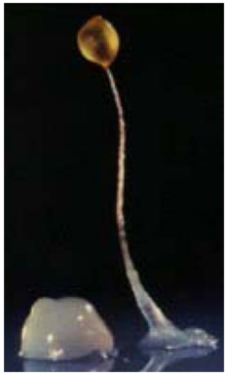
Milind Watve

Department of Microbiology,

Abasaheb Garware College, Pune.

Living world relies on altruism and cooperation between individuals

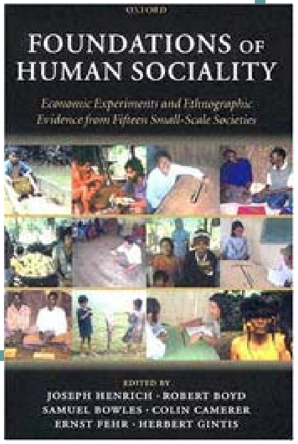
Myxobacteria rely on social behaviors that help them in cooperative feeding and formation of fruiting bodies.



Social amoeba responds to environmental stress by forming fruiting bodies that involve altruistic suicide by some cells.

Honeybees, social wasps and naked mole rats are just few of the many eusocial systems.

While humans, who have achieved one of the pinnacles of sociality, often cooperate with genetically unrelated strangers, in a large group and when reputation gains are small or absent.



Constraints on the evolution of altruism

Darwinian struggle for existence and survival of the fittest situates an economic barrier on the evolution of cooperation.

If group beneficial norms are costly to the individuals who perform them then the cheaters who get the benefit of the group without actually contributing to it will be more successful than altruists and selection will favor cheaters.

Yet cooperation and altruism is common in living world.

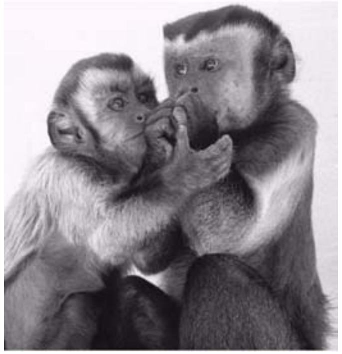
How does this cooperation evolve?

Definitions

- **ALTRUISM:** behavior that involves a fitness cost to one individual or cell (the altruist) and a fitness benefit to another individual or cell (the recipient of the altruistic act).
- **COOPERATION:** multiple individuals or cells engaging in a common task for mutual benefit.
- **COLLECTIVE ACTION**: The combined effect of individual behaviors within a group.
- **DIVISION OF LABOR:** two or more classes of individual or cell engaging in specialization involving complementary, synergistic behavior.

- **CHEATING:** engaging in behavior that exploits the cooperative behavior of con-specifics by imposing fitness costs on them, while providing fitness benefits to the cheaters.

What can evolve altruism?

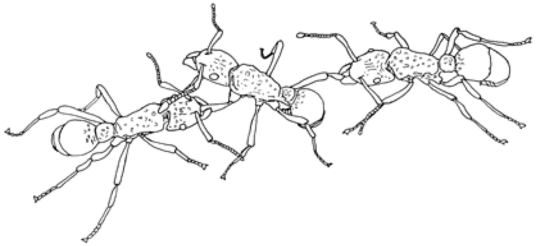


Kin Selection: Natural selection for alleles shared by close relatives that might cause individuals to behave in a manner that is detrimental to their own individual fitness but beneficial for the spread of the alleles under selection.

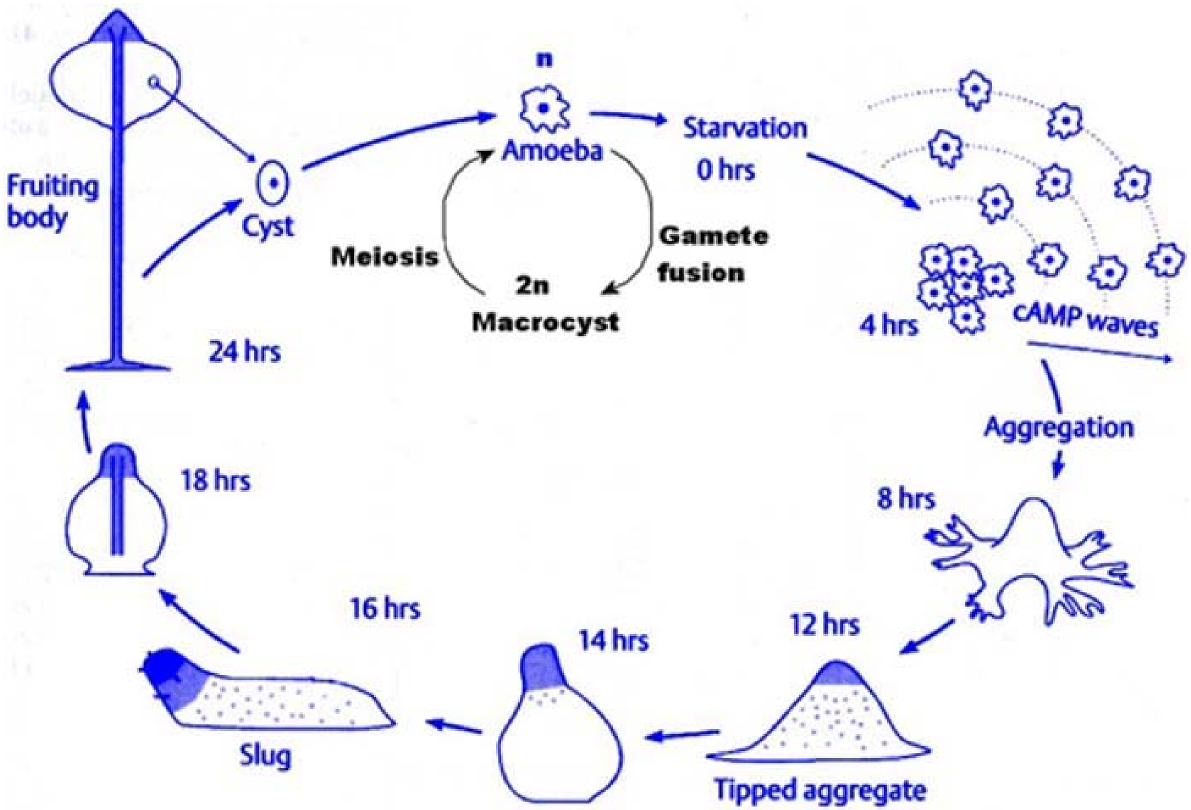
Reciprocal altruism: Works by the principle "you scratch my back and I will scratch yours".

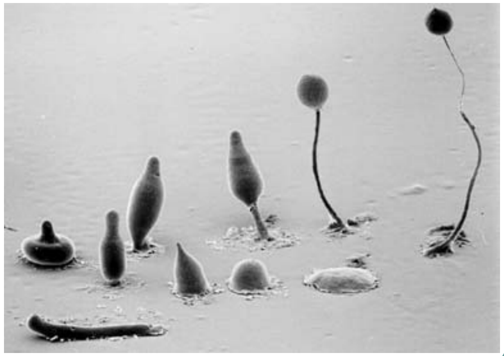
Reputation: Works by the principle " I won't scratch your back if you won't scratch their backs".

Strong reciprocity: Rewarding a cooperator and punishing a defector.

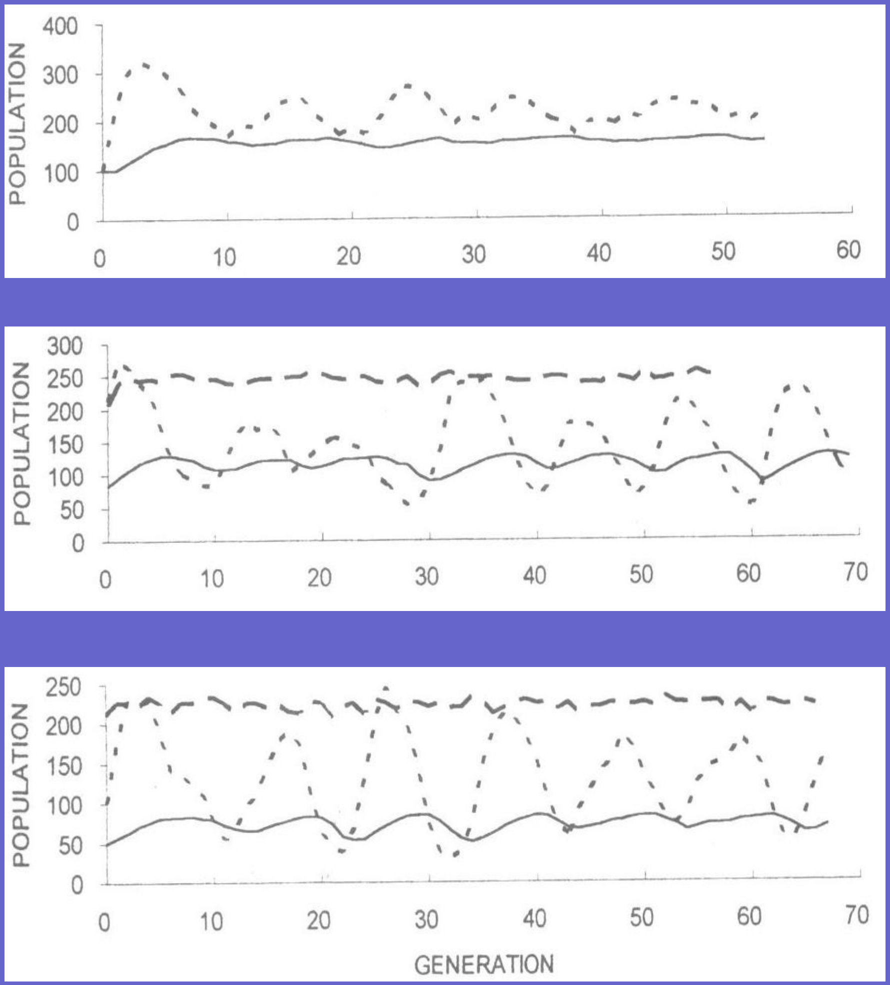


Cheaters can exploit cooperation in social amoeba *Dictyostelium*

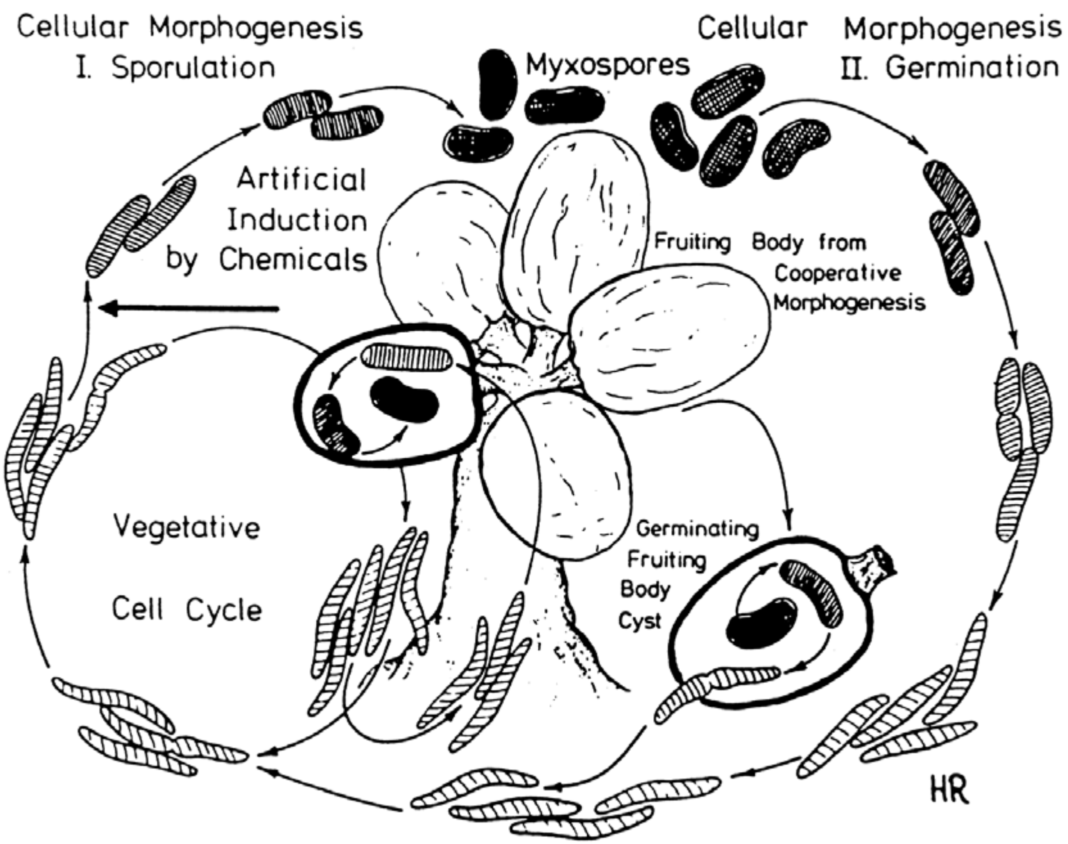




Altruists and cheaters can coexist in *Dictyostelium*



Social strife in Myxobacteria



Myxobacteria rely on cooperation between individuals as they feed on complex organic substrates and form fruiting bodies under nutrition scarcity. Since more than 90% of the cells sacrifice their lives for the formation of the fruiting body, cheaters who fail to contribute to the group beneficial tasks exploit this social system.

To produce or not to produce nectar: The tale of the cheater flowers

- Pollination of flowers by insects is a major contributor to fitness in cross-pollinated angiosperms, and nectar is the most common reward of pollinators.
- Production of nectar is costly as it exerts a considerable drain on the resources of plants.
- If pollinators cannot detect the presence of nectar before entering flowers, then flowers may cheat by not producing nectar.
- However, avoidance learning by pollinators can decrease the success of nectarless plants.
- Nonetheless a stable proportion of nectarful and nectarless flowers can coexist.

A model of insect learning and evolution of nectarless cheater flowers

$$R = BR + \frac{(R_{max} - BR)N}{K + N} - C \times N$$

R = reproductive success of an individual plant producing a proportion N of nectarful flowers.

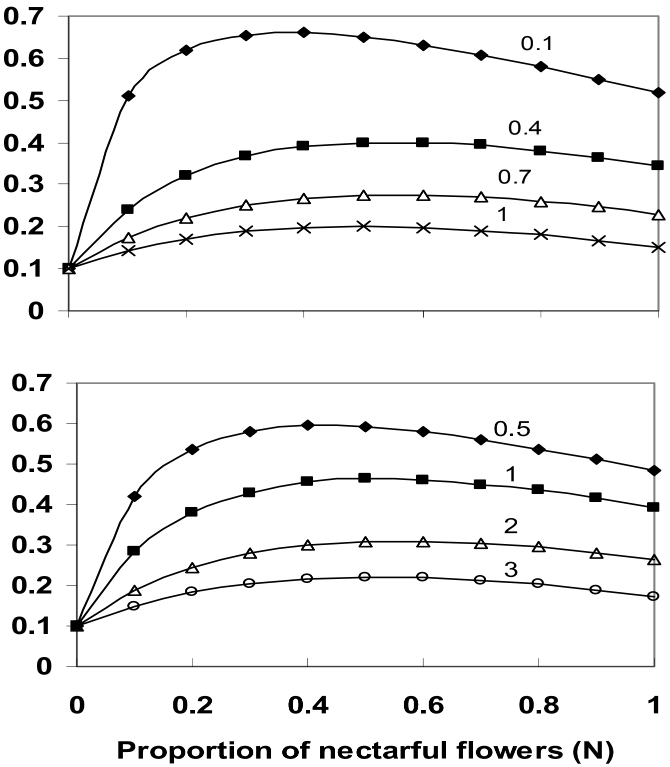
R_{max} = maximum possible reproductive success.

BR = reproductive success gained by random visits by pollinators

N = stable proportion of nectarless flowers

K = Michaelis – Menten constant.

C = cost of nectar production per flower



Reproductive success as a function of nectarless flowers when maximum reproductive success is unity.
(a) L = 1, (b) A = 0.3

Derivations of equations

If the maximum reproductive success is unity:

$$R = BR + \frac{N(1-BR)}{(A \times L + N)} - N \times C$$

Thus the change in R with increasing N can be given as,

$$\frac{dR}{dN} = \frac{(A \times L + N)(1-BR) - (1-BR)N}{(A \times L + N)^2} - C$$

R can be maximized at dR/dN = 0, therefore

$$\frac{(1-BR)A \times L}{(A \times L + N)^2} = C$$

For every value of A there will be an optimum N. If N < A, A will decrease. If A < N, A will increase and if A = N a stable proportion of nectarless and nectarful flowers will coexist.

Evolutionary stability of cheater flowers

Both, nectarfull and nectarless flowers, will coexist with the evolutionary stable proportion of nectarless flowers given by following formula.

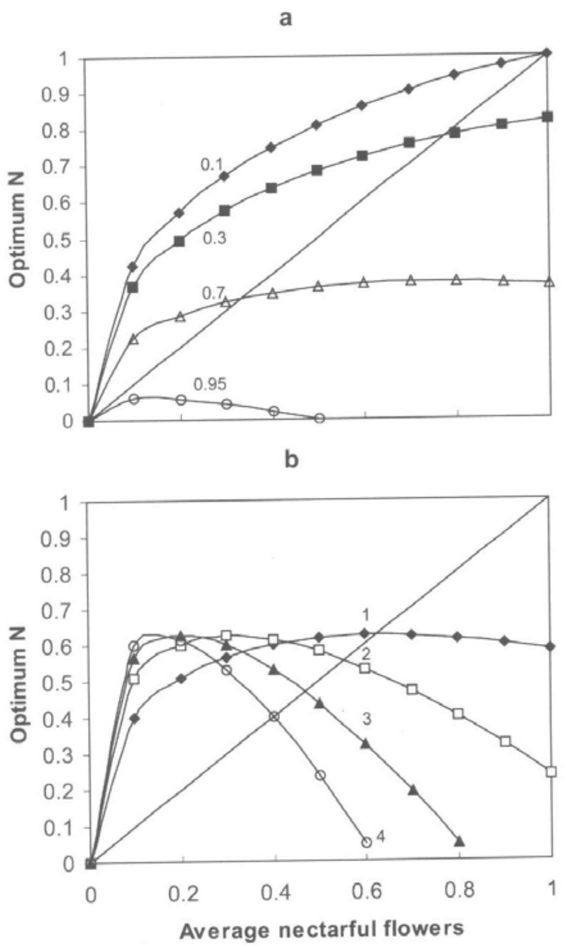
$$N^* = \frac{(1 - BR)\,L}{C\,(1 + L)^2}$$

N* = stable proportion of nectarless flowers

BR = reproductive success gained by random visits by pollinators

C = cost of nectar production per flower

L = constant inversely proportional to pollinator learning ability



The future of altruists and cheaters