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Supplementary information

Ten recent insights for our understanding of cooperation

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Ten Recent Insights for Our Understanding of Cooperation

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Supplementary Information

1. Supplementary Information: Relatedness and Cooperation

Insight 1summarises how relatedness (R) between interacting individuals has been shown to have a clear and consistent influence on the evolution of cooperation. Here, we summarise this data in two tables.

Organisms	**Group formation**	**Pattern**
Asexual single-celled organisms (e.g. bacteria, fungi and slime moulds)	Staying versus aggregating	Species that form groups by staying with their parent (clonal groups, R=1): (i) are more likely to have altruistic sterile helpers; (ii) have larger social groups; (iii) have more cells types (greater division of labour); compared with species that form groups by aggregating (potentially non-clonal, R<1)[1].
Birds	Staying versus aggregating	Species that form groups by offspring remaining at the nest, with their parents, show higher levels of cooperation, compared with species that form groups by aggregating[2].
Insects	Staying versus aggregating	Within social insect species where groups can be formed in both ways, groups that form by remaining with their parents cooperate at higher levels than groups that form by aggregating[3].
Bacteria, Fungi	Number of clones per group	When relatedness is manipulated experimentally, cooperation is favoured when relatedness is high, but not when relatedness is low[4-8].
Birds	Monogamy	Across birds species: (i) females of cooperative species mate with less males, and are more likely to be monogamous, than species which do not breed cooperatively[9,10]; (ii) evolutionary transitions from non-cooperative to cooperative breeding tended to occur in relatively monogamous species, where males mate with less females[9,10]; (iii) the percentage of nests that have cooperative helpers is higher in

		species where females mate with fewer males[10]; (iv) helpers provided more food to offspring in species where the helpers were more related to the young they were provisioning[11].
Mammals	Monogamy	Cooperative breeding has only evolved in socially monogamous species where females tend to only mate one male[12].
Insects	Monogamy	Eusociality has only evolved in species with lifetime monogamy[13,14].
Shrimps	Monogamy	The evolution of cooperative breeding is associated with monogamy[15].
Ants & bees.	Monogamy	Species with either multiple mating or multiple queens, showed greater polymorphism in genes upregulated in the worker caste compared with genes upregulated in the reproductive caste[16-18].

Supplementary Table 1. Group formation and cooperation. The method of group formation determines relatedness within that group. The method of group formation is consistently correlated with whether and how much cooperation occurs, across the tree of life. The citations are examples and not exhaustive.

Influences relatedness	**Increased cooperation in**	**Form of evidence**
Staying together (with parents)	Bacteria, birds, fungi, insects, mammals, shrimps, slime moulds, viruses.	Comparative across species, experimental evolution, genomic.
Monogamy	Birds, insects, mammals, shrimps.	Comparative across species, genomic.
Kin discrimination	Birds, insects, mammals, shrimps, slime moulds.	Comparative across species, experimental, observational.

Supplementary Table 2. Relatedness and cooperation. The same factors have been implicated in determining relatedness and the level of cooperation time and time again, across diverse taxa, and with a variety of methodologies. Our summary is illustrative not exhaustive.

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