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A fish on a roll? A snake that's a loser? It may sound absurd, but Lee Dugatkin's research suggests that the way animals and humans take victory and defeat shapes our Societies

IT'S a jungle out there. Beneath the thin veneer of civilisation, life for *Homo sapiens* is as cut-throat as it is for any other animal. Like them, we are in constant competition for the things that really matter: sex, material comforts and real estate. Inevitably, there are winners and losers. And our societies, like most groups of animals, are organised hierarchically, with a few big-hitters wielding most of the power and the vast majority of us somewhere further down in the pecking order.

But hold on. Surely this is one area where we are nothing like other animals. Don't they simply rely on size and strength to fight their way to the top? Well, that's what we used to think, but it's becoming increasingly apparent that although other species can't argue their case to get what they want, neither is brawn all that counts.

In many animals, the outcome of any clash is also shaped by subtle psychological factors—like us, they have their winning and losing streaks. Past experiences matter, and the behaviour of members of a particular species is affected in characteristic ways by winning, losing, or simply by watching a fight.

What's more, these psychological factors seem to have a drastic effect on animal societies and the levels of aggression within them. My own studies indicate that they can be used to make predictions such as whether interactions between group members will be autocratic or meritocratic, and whether there will be peacekeepers to break up fights before they get out of hand. The same rules may even help explain the dynamics of human societies.

Another researcher looking at these so-called winner, loser and bystander effects is Gordon Schuett from Arizona State University West in Tempe. While many of us shy away from studying animals that might kill us, Schuett is made of sterner stuff—he is studying the deadly copperhead snake, *Agkistrodon contortrix*. Most copperhead aggression is between males fighting for access to females, and to find out whether winning or losing affects a snake's performance in subsequent fights, Schuett placed a female in the centre of an arena and then put a male at each end. The males had not been in a fight for between six and 12 months before the study, so they came into the ring as "blank slates" in terms of winner and loser effects.

At first, size mattered: in every one of 32 fights, the larger male copperhead emerged as the victor and won the female. But Schuett was more interested in what would happen next. Once the initial battles were complete he grabbed 10 winners and 10 losers and pitted each against a new male of the same size that had no prior fighting experience. He found first-round winners were no more likely to win than were their opponents—in other words, there was no winner effect. But males that had previously lost were very likely to lose again. What's more, when two-time losers were given one last chance to prove themselves, the results were even more dismal—not one of these males won a fight. Schuett had found a clear case of the loser effect in action.

In recent years, similar experiments have revealed that the performance of numerous species of insects, fish, birds and mammals is influenced by winning or losing. Many animals, including swordtail fish, blue gouramis, crickets and

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rats, display both winner and loser effects. Several, like the copperhead snake, are only affected by losing. Other examples are pumpkinseed sunfish, green sunfish and paradise fish. So far, we've found no species where winner effects occur in isolation but time will tell.

There can be no doubt that winner and loser effects exist, and when animals square up to fight, these effects matter. But animals don't fight in a social vacuum. Fights are the basis for dominance hierarchies—the status ladders that can determine who gets what resource, and just how much they get. Over the past five years, my colleagues and I have been using computer simulations to examine how winner and loser effects influence the formation and stability of social hierarchies. Do these effects have implications for how animals fight? And do they shape the sort of hierarchies we find in different groups?

In our digital arena, we start off with four players who are each assigned an "initial fighting ability score". Individuals are then paired up at random to fight. Each player has two pieces of information about itself: its initial fighting score, and how that score has changed as a result of subsequent wins and defeats. If a winner effect is operating, after each victory a player's score goes up. Conversely, if a loser effect is in play its score goes down if it is beaten.

The player also knows the initial fighting score of the opposition—but not the cumulative score that reflects their past performance. The assumption here is that initial fighting ability represents physical attributes that are obvious to any onlooker, such as size, whereas a player's cumulative score is determined by experience, which is not apparent to anyone but the player. So individuals have more information about themselves than their opponents, which is usually how things are in the real world.

When two players square up inside the computer, one of three things happens. If both opt not to fight, they simply go their separate ways. This usually happens if both have low estimations of their own fighting abilities, and it represents the sort of posturing often seen among wild animals. If one individual chooses to be aggressive (because it has a high estimation of its own score compared with that of its opponent), but the other does not (for the opposite reason), then an "attack-retreat" sequence is logged. This is the virtual equivalent of a pair of real animals settling a dispute by one charging and the other cowering. Finally, a fight may occur if both players think they have a chance of winning because each considers its score to be higher than the other's. In this case the winner is the one with the highest cumulative fighting score.

These simulations can be acted out with winner effects alone in place, loser effects alone, or both operating simultaneously. And the surprise is that winner and loser effects produce very different hierarchies. When winner effects are in play, a linear hierarchy emerges with a clear pecking order. For example, A dominates B, who dominates C, who dominates D. It is the sort of hierarchy you find among pigeons, many species of insects and group-living canids, such as wolves and hyenas. Watching such creatures interact, it's obvious that each individual is aware of its rank, and the rank of every other animal in the group.

When loser effects alone are operating, a much more autocratic hierarchy surfaces, like those you find among gorillas and many species of fish and insects. In these social groups, the top-ranked or "alpha" individual is obvious, but the rank of the other members in the group is hard to work out because they seldom interact. This sort of hierarchy also emerges when both winner and loser effects are in play.

Even more intriguing is the finding that there are major differences between the types of social interaction in these two sorts of society. Fights are the name of the game when winner effects alone are in play. Here, each individual can only increase its estimation of its own fighting skills, so everyone is raring for a fight. The attack-retreat scenario, on the other hand, is most likely to arise where loser effects are in play or where both effects occur simultaneously. Here, many individuals have a low estimation of their fighting abilities and are likely to avoid aggressive interactions whenever possible.

Intrigued by these findings, we decided to extend our model to include "bystander effects". In these, animals change their estimation of the fighting ability of others as a result of observing them in action. In other words, A changes its estimation of B's fighting ability depending on how B does in a fight with C. If A notches up its estimation of B's abilities when B wins, that's called a bystander winner effect. If A lowers its estimation of B when B loses, that's a bystander loser effect. Bystander effects seem to be involved in the original pecking order—that of chickens. When birds have just lost a fight they are often attacked by onlookers, whereas this rarely happens when they have just won.

More rigorous evidence that bystander effects occur in nature comes from a recent study by my colleague Ryan Earley. He used trios of male swordtail fish to test the idea. First he allowed pairs of combatants to slug it out on one side of a partition while a third male sat the match out on the other side. Then he pitted the third fish against either the winner or the loser.

In some of the experiments the partition was transparent, in some it was opaque, and in others it was a one-way mirror that let only the observer view the combatants. Earley found that watching the initial fight affected the outcome of the second round. Bystanders were less likely to win against fish they had observed winning—a bystander winner effect. But they were also no more likely to win against a fish they'd observed losing—there was no "bystander loser effect".

Confident that bystander effects are real, we put them into our computer model to see how they would affect the virtual pecking order. Once again, we assigned our four cyberfighters an initial fighting ability score, but instead of increasing or decreasing their own score, they would change their estimation of the scores of others. When bystander winner effects alone are in play a strange hierarchy emerges—one that doesn't seem to reflect any society in the real world. Only the lowest-ranked group member (omega) is clearly delineated, while the ranks of the other three are unclear. But we know they attack the omega whenever possible, and the omega always retreats.

When bystander loser effects alone are in operation, however, we get no discernible hierarchy—all four players are equally likely to win or lose in a showdown. What's more, these encounters are invariably aggressive, with both parties spoiling for a fight. According to our simulation, bystander loser effects are stronger than bystander winner effects, so if both are in operation the society is likely to be non-hierarchical and aggressive.

What happens when winner, loser and bystander effects are all in operation at the same time? As with the winner effect alone, group members are clearly ranked, but this time instead of fighting, most interactions take the form of attack and retreat. Sounds familiar? Unfortunately, no one has examined winner, loser and bystander effects in humans, but my bet is that when they do, we shall find that all of these are in play in our species. In the meantime, it is interesting to note that many human societies do seem to be organised in clear, linear hierarchies, but with not all that much real fighting going on—just as our model predicts.

It seems amazing that something as simple as attitudes to winning and losing should have such huge implications for social organisation and the dynamics of aggression. But our models continue to surprise us with their predictive power. We are finding that these effects can explain other behaviours such as intervention—where an impartial bystander steps in to break up a fight. We're used to this sort of behaviour in humans, but it also occurs in other primates and has even been observed in cichlid fish. Indeed, our model predicts that intervention is favoured whenever winner effects are in play. That's because when an individual breaks up a fight between others, it prevents anyone from winning and getting "on a roll" which might later give them an advantage over the animal doing the intervening.

There's no similar benefit to intervening when loser effects alone are in play, because here you're breaking up a fight that will produce a loser who is likely to lose against you in the future. So we predict that these sorts of societies wouldn't have peacemakers.

Of course, our cyberfighters and virtual peacemakers do not experience the myriad environmental factors that influence the behaviour of animals in the wild. But by paring social interactions down to basics we are starting to see that simple biases can drastically alter the shape a society takes and the levels of aggression exhibited by the animals within it. To get the full picture, we'll need to combine our findings with a lot more research on real animals—and that's not as simple as interacting with a computer screen.

But results are starting to emerge. For example, a recent study by Rui Oliveira and his colleagues at the University of Lisbon shed some light on the thorny question of how winning, losing or watching a fight affects an animal's subsequent performance. Oliveira's team found that when male cichlid fish observe a fight their androgen levels rise. The researchers suggest that this might fire up onlookers to attack losers—and increase their chances of beating them.

In other words, these fish experience a surge of sex hormones rather like the

surge of testosterone my friends from Brooklyn used to get from watching a good hockey fight.

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FURTHER READING

Further reading: "Watching fights raises fish hormone levels" by Rui Oliveira and others, *Nature*, vol 409, p 475 (2001).

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