BIOSCIENTIST
The Salford Biomedicine Society Magazine

Parasites: Friend or foe?

Muhammed Amla

Accounting for nearly 40% of all species on Earth[1], parasites are organisms which survive and reproduce by forming symbiotic relationships with other organisms (known as hosts in this relationship) which benefit the parasite and generally harm the host. Many parasites cause death and disease, but they also have helpful roles in health, industry, crime, and agriculture.

Why are parasites important?

While they are not holidaying in your guts or using their host as live cocoons[2], parasites can actually be greatly beneficial, from improving agriculture to triggering major evolutionary changes:

Farming

With an estimated 20-40% of global agriculture lost to insects, parasites may offer a far more effective solution than damaging farmlands with costly pesticides. Parasitoids are insects behaving like parasites that kill their hosts in the process[3], with many naturally preying on crop pests.

One example is the Aphidius ervi, a parasitic wasp that lays its eggs in aphids, turning the aphids into a parasitised mummy[4]. Within 2 weeks, the offspring eat their way out of the aphid, searching for more aphids and perpetuating the cycle.

UK rapeseed oil production is hindered by midges. Several wasp parotoids, such as the Platygaster subuliformis attack these midges, killing up to 75% of their larvae[5]. This non- chemical control of pests not only reduces damage to farmland, but also to health of the farmers. Indeed, it is widely accepted that long-term pesticide exposure is linked to Parkinson’s disease, asthma, depression, ADHD, anxiety, and cancers[6].

DOI: https://doi.org/10.57898/biosci.134

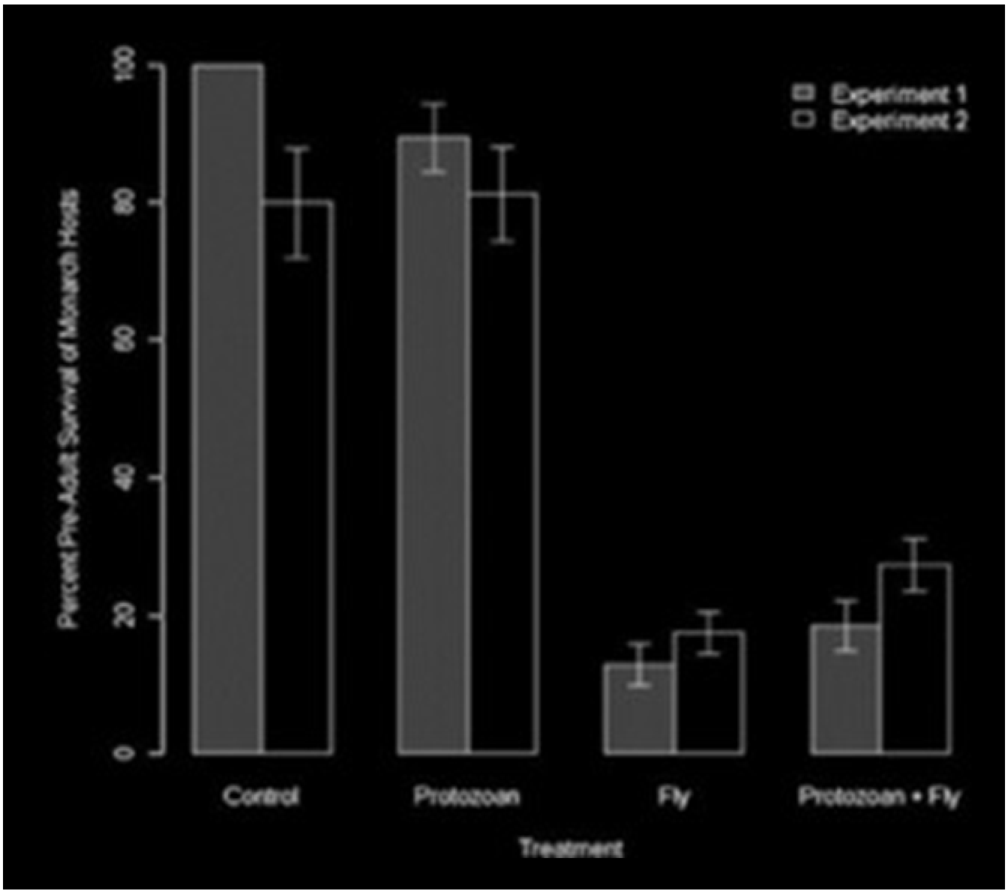

Figure 1: Monarch survival to adulthood when exposed to the protozoan parasite, fly alone, and the protozoan and fly combined[10]

Boosting the immune system

Being infected is not always a terrible thing. In some cases, it can supply more benefits, such as increased protection in hosts from infection by pathogens. Enterococcus faecali, a mildly pathogenic bacteria living in worms, can evolve rapidly to protect their hosts from more lethal infections[7]. This blurs the line between parasitic relationships, where the parasite feeds from the host while causing harm, and mutualistic relationships, where the parasite and host both provide benefits to each other.

There are two forms of protection a parasite can provide to its hosts: resistance, and tolerance[8]. Parasites that provide resistance reduce the likelihood of other species infecting. For example, bacteria in the gut resist the invasion of non-native species. This specific example is also known as colonisation resistance[9]. Meanwhile, parasites providing tolerance reduce the harm of another invading species. For example, when Monarch Butterfly Larvae are inoculated with Ophryocystis elektroscirrha, a virulent protozoan parasite, they have a higher chance of survival when attacked by the lethal parasitoid fly, Lespesia archippivora, than if exposed to the parasitoid alone (Figure 1)[10].

Research has shown that when infected with an intestinal worm, the number of lymphoid follicles (microscopic compartments storing B cells, which produce antibodies against pathogens) in mice increased.

The body naturally produces more B cells to increase antibody production in response to an infection, but it does not typically increase the number of lymphoid follicles. However, upon infection with intestinal worms, a cytokine molecule (IL-4) is produced which stimulates B cells to produce lymphotoxin. This then interacts with stromal cells, which produce another cytokine (CXCL13) stimulating follicle production in the lymph nodes[11].

DOI: https://doi.org/10.57898/biosci.134

B cell follicle formation was previously thought to only occur during the post-natal period (immediately after birth), but this research showed that this process can also occur in adult mammals in the event of a worm infection[12]. While it is not recommended to use intestinal worms directly to boost the immune system, it is important to note that they do strengthen the immune system uniquely and this may shape novel research and ultimately treatment strategies in the future.

Another study involving amphibian hosts and trematode parasites displayed how parasite richness not only dampens pathogen transmission, but also inhibits the spread of Ribeiroia ondatrae, a deadly parasite which causes limb malformations in amphibians[13].

Driving evolutionary change

While there are a wide variety of other factors that influence evolutionary change and diversity, it can be said that parasitic organisms could also have played a key role. It is important to note that the following are mainly theories, with many other factors contributing towards evolutionary change, as opposed to exclusively or mainly parasites.

It is hypothesised that parasites drive organisms to become more diverse and complex.

The constant evolutionary arms race between the two promote increased defences by the host against the parasite, meanwhile the parasite increases its effectiveness to infect its host. Using computer programs and parasitic programs in a simulation, it demonstrated how diverse lineages arise from the coevolution of hosts and parasites, encouraging then to form complex traits[14]. Similar demonstrations with bacteria[15] also indicate the importance of parasites, showing a noticeable effect on population dynamics and evolution.

Parasites and sex

Another hypothesis is parasites could have influenced the existence of sexual reproduction. One advantage gained, from shuffling genes and producing genetically diverse offspring, is surviving parasites more effectively. The presence of parasites can encourage the constant genetic turnover and force hosts to keep evolving[16].

An experiment conducted with worms and parasites displayed how selfing populations were wiped out within 20 generations, as opposed to outcrossing populations which persisted throughout the experiment[17]. Male snails also start to disappear from the population in areas where parasites are rare, favouring asexual reproduction over sexual, due to the substantial costs of sexual reproduction[18].

Parasites and the brain

Certain parasites have been known to manipulate host behaviour, for example Toxoplasma gondii, which diminishes a rodent’s predator evasion around cats, turning it into an easy meal. Other examples include rabies, and some sexually transmitted pathogens have been known to influence sexual behaviour. It can be suggested that the human central nervous system has evolved to be incredibly complex as a protective countermeasure against parasites that influence behaviour.

The blood brain barrier is a first line defence from pathogens and toxins present within the bloodstream[19]. In the constant arms race,

there are other parasites that have evolved to pass the barrier using white blood cells and monocytes as a mode of transport[20]. Some parasites can cleverly manipulate behaviour externally, for example Toxoplasma gondii increases dopamine, a behaviour altering substance[21]. Others can secrete different hormones and activate specific immune responses to manipulate their host to complete their life cycle or leach resources.

Another countermeasure to protect the brain against behavioural changes by parasites is an increase in the amount of neurochemicals required to induce responses. Some parasites release neurochemicals to alter behaviour, the more required to create a response, the greater metabolic cost on the parasite. Due to the

DOI: https://doi.org/10.57898/biosci.134

generally large size difference between host and parasite, it renders the attack ineffective. The relentless pressure from the increasing brain size through the course of human evolution could have led to parasites adopting alternative strategies[22].

Rather than the parasites directly attaching and physically affecting the brain, some parasites like Ophiocordyceps unilateralism almost never touch the brain, yet precisely control insect behaviour[23].

Another advantage of increasing brain size is developing higher levels of protective complexity, meaning they can take more damage while maintaining normal functionality and behaviour. For this reason, mind controlling parasites are more commonly seen in insects. Increasing neuro- signalling complexity, with the use of a range of receptors, neurochemicals, and timed pulses, closes off a parasite's attacking options. While more complex signals have an increased metabolic cost, it is disproportionately more expensive for parasites, forcing other means of manipulation[22].

References

1. Dobson A, Lafferty KD, Kuris AM, Hechinger RF, Jetz W. Homage to linnaeus: How many parasites? How many hosts? In: In the Light of Evolution. Vol 2. National Academies Press (US); 2008:63-82. doi:10.17226/12501

2. Gabbatiss J. Prehistoric parasitic wasps found frozen inside fossilised victims named "Xenomorphia" after terrifying creature in Alien films. The Independent. https://www.independent.co.uk/news/science/wasp-parasite- fossil-discovery-insects-x-rays-a8511316.html. Published 2018.

Accessed February 25, 2021.

3. Natural History Museum. Positive parasites. Published 2016. Accessed February 25, 2021. https://www.nhm.ac.uk/discover/positive-parasites.html

4. Dragonfli. Aphid Parasite Wasp - Aphidius colemani. Published 2018. Accessed February 25, 2021. https://www.dragonfli.co.uk/products/aphid-parasite-wasp- aphidius-colemani

5. AHDB. Encyclopaedia of pests and natural enemies in field crops. Published online 2016. Accessed February 25, 2021. https://cereals.ahdb.org.uk/media/524972/g62-encyclopaedia- of-pests-and-natural-enemies-in-field-crops.pdf

6. PAN. Impacts of pesticides on our health. Published 2021. Accessed February 25, 2021. https://www.pan-uk.org/health- effects-of-pesticides/

7. King KC, Brockhurst MA, Vasieva O, et al. Rapid evolution of microbe-mediated protection against pathogens in a worm host. ISME J. 2016;10(8):1915-1924. doi:10.1038/ismej.2015.259

8. Ashby B. Parasites inside your body could be protecting you from disease. The Conversation. Published 2017. Accessed February 25, 2021. https://theconversation.com/parasites- inside-your-body-could-be-protecting-you-from-disease-83068

9. Pickard JM, Zeng MY, Caruso R, Núñez G. Gut microbiota: Role in pathogen colonization, immune responses, and inflammatory disease. Immunol Rev. 2017;279(1):70-89. doi:10.1111/imr.12567

10. Sternberg ED, Lefèvre T, Rawstern AH, de Roode JC. A virulent parasite can provide protection against a lethal parasitoid. Infect Genet Evol. 2011;11(2):399-406. doi:10.1016/j.meegid.2010.11.017

DOI: https://doi.org/10.57898/biosci.134

11. Dubey LK, Lebon L, Mosconi I, et al. Lymphotoxin-Dependent B Cell-FRC Crosstalk Promotes De Novo Follicle Formation and Antibody Production following Intestinal Helminth Infection. Cell Rep. 2016;15(7):1527-1541. doi:10.1016/j.celrep.2016.04.023

12. ScienceDaily. Intestinal worms boost immune system in a surprising way. Published 2016. Accessed January 1, 2021. https://www.sciencedaily.com/releases/2016/05/1605051350 32.htm

13. Johnson PTJ, Preston DL, Hoverman JT, LaFonte BE. Host and parasite diversity jointly control disease risk in complex communities. Proc Natl Acad Sci. 2013;110(42):16916-16921. doi:10.1073/pnas.1310557110

14. Zaman L, Meyer JR, Devangam S, Bryson DM, Lenski RE, Ofria C. Coevolution Drives the Emergence of Complex Traits and Promotes Evolvability. Keller L, ed. PLoS Biol. 2014;12(12):e1002023. doi:10.1371/journal.pbio.1002023

15. Betts A, Gifford DR, MacLean RC, King KC. Parasite diversity drives rapid host dynamics and evolution of resistance in a bacteria-phage system. Evolution. 2016;70(5):969-978. doi:10.1111/evo.12909

16. Jones L. What would happen if all the parasites disappeared? BBC. Published 2015. Accessed January 1, 2021. http://www.bbc.co.uk/earth/story/20150127-what-if-all-the- pests-vanished

17. Morran LT, Schmidt OG, Gelarden IA, Parrish RC, Lively CM. Running with the Red Queen: Host-Parasite Coevolution Selects for Biparental Sex. Science. 2011;333(6039):216-218. doi:10.1126/science.1206360

18. Lively CM. Trematode infection and the distribution and dynamics of parthenogenetic snail populations. Parasitology. 2001;123(SUPPL.):S19-26. doi:10.1017/s0031182001008113

19. Götz J. Explainer: what is the blood-brain barrier and how can we overcome it? The Conversation. Published 2017. Accessed January 1, 2021.

https://theconversation.com/explainer-what-is-the-blood-brain-barrier-and-how-can-we-overcome-it-75454

20. Masocha W, Kristensson K. Passage of parasites across the blood-brain barrier. Virulence. 2012;3(2):202-212. doi:10.4161/viru.19178

21. Prandovszky E, Gaskell E, Martin H, Dubey JP, Webster JP, McConkey GA. The Neurotropic Parasite Toxoplasma Gondii Increases Dopamine Metabolism. PLoS One. 2011;6(9):e23866. doi:10.1371/journal.pone.0023866

22. Packham C. Did parasite manipulation influence human neurological evolution? Phys.org. Published 2019. Accessed January 1, 2021. https://phys.org/news/2019-08-parasite- human-neurological-evolution.html

23. Yong E. How the Zombie Fungus Takes Over Ants' Bodies to Control Their Minds. The Atlantic. Published 2017. Accessed January 1, 2021. https://www.theatlantic.com/science/archive/2017/11/how-the-zombie-fungus-takes-over-ants-bodies-to-control-their- minds/545864/

DOI: https://doi.org/10.57898/biosci.134