# Microbial Record Breakers

**Professor Robin May**

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Humans love competition. Since ancient times, public demonstrations of physical or mental prowess have drawn large crowds. Today 'record-breaking' is big business; witness the sell-out crowds that attend the Olympics or Commonwealth games. Those of us that are not blessed with superhuman abilities watch in awe as others swim at breakneck speed, run astonishing distances in remarkable times, or perform numerous other feats that seem to defy normal possibilities.

However, when it comes to breaking records, human endeavours pale into insignificance in comparison with some of the super-athletes found in the microbial world. In this lecture, we will take a ringside seat for the Microbial Olympic Games and, in doing so, learn a bit about how microbes achieve some truly astonishing physical feats.

## Life in the Fast Lane

We start our exploration of microbial record-breakers in the same way that the Ancient Greeks started the Olympics; with a contest of speed. Many microbes are motile and they use a variety of means to do so. Single-celled eukaryotes like amoebae often crawl; extending cellular projections in the direction they want to travel and then squeezing their flexible 'bodies' behind, rather like a self-propelling tube of toothpaste. However, it is within the flagellated bacteria that we find the fastest swimmers.

We encountered the bacterial flagellum in an earlier lecture. This remarkable molecular machine is rather like an extended corkscrew, attached to a motor that is embedded in the bacterial membrane. As the motor spins, the corkscrew pushes the bacterium forwards. At room temperature, the 'model' bacterium *Escherichia coli* spins its motor at about 125Hz (the equivalent of 7500rpm), although some other bacteria can run their motors almost five times faster. This enables *E. coli* to swim at a blistering 50 micrometres per second; in human terms, the equivalent of completing the 100m sprint in two seconds. This is all the more impressive when one realises that – at this microscopic scale – the viscosity of water is essentially equivalent to syrup. And yet, in our Olympic line-up, *E. coli* wouldn't even finish on the podium – other bacteria such *Vibrio cholerae* (the causative agent of cholera) are at least twice as fast and would easily claim gold in this particular microbial competition.

## Under Pressure

Our next record-breaking challenge is a feat of strength. The current world record for human weight-lifting is 267kg, which roughly equates to a pressure on the lifter's foot of around 100kPa, or half the pressure of a car tyre. Compare that, though, to the rice blast fungus, *Magnaporthe grisea*, which is responsible for massive rice crop losses around the world. To gain entry to the rice leaf, the fungus produces an adhesive pad called an appressorium, which applies increasing amounts of pressure until it literally blasts its way into the plant. At peak, this appressorium can generate an astonishing 8Mpa – the equivalent of a human lifting a 21000kg set of weights, or a Chinook helicopter.

Of course, strength isn't just about how much force you can apply outwardly – it also matters how much external pressure you can resist. Humans are particularly bad at this kind of pressure – our squishy bodies with their internal skeletons mean that an increase in atmospheric pressure of three or four-fold are usually fatal. In contrast, the Deepsea Challenge expedition recovered a live bacterium, *Colwellia marinimaniae*, from the bottom of the Mariana Trench, almost 11km below the sea surface and living at a thousand times normal atmospheric pressure; the equivalent of us balancing 100 adult African elephants on our head.

## Live Fast, Die Young…

Humans are fairly obsessed with lifespan and, in particular, how to extend it whilst remaining fit and healthy. 'Lifespan' in the microbial world can be a tricky concept, given that most bacteria reproduce by binary fission; a process in which the bacterium elongates and then divides in half, producing two daughter cells. If, though, we assume that the time between one division event and the next is a single generational 'lifespan', then bacteria can claim the record for both the fastest and the slowest. Under optimal growth conditions, *E. coli* can divide every 17 minutes, giving it a fair claim to be one of the fastest reproducing organisms on Earth – compensation, perhaps, for having missed out on the speed record earlier. Even larger, more complex microbes such as yeast can divide in under an hour. This, of course, is one of the reasons that microbial infections can progress so swiftly – under perfect conditions, a single bacterium can become 1 billion within 12 hours.

At the other end of the scale, however, you have the record-breaking tortoises of the microbial world. Many bacterial species live in extreme environments where nutrient availability, external temperature or other factors are far from ideal for growth. For most multicellular organisms, life would be impossible in such circumstances. But many microbes adopt a strategy of extreme stress resistance, hunkering down and maintaining biochemical processes at a barely detectable rate. And when we say slow, we mean really, really slooooooow. Scientists have recovered bacteria from Antarctic ice that can be coaxed to divide after at least 8 million years encased in ice. However, even that pales into insignificance relative to microbial samples retrieved from deep below the seabed, which appear to have existed there for over 100 million years, dividing at the glacial rate of once every 10 000 years. To put that in perspective, many of the bacteria in those samples last divided when woolly rhinoceros and sabre-toothed cats roamed the world.

A fascinating but as yet unanswered question is how such cells avoid damage (for instance, from thermal fluctuations or UV rays) over such extended periods – are they 'locked' in a fully dormant state, or 'ticking over' at an extremely low metabolic rate that nonetheless enables them to repair cellular damage? An understanding of those microbial maintenance processes may one day help humans avoid some of the DNA damage that is currently a barrier to long-distance space travel, or even allow us to put humans into similar states of 'suspended animation'.

## Powerful Projectiles

The human Olympic Games involves several events in which athletes hurl projectiles at remarkable speeds or over remarkable distances. But in these sports, as in so many others, it is the microbial competitors that win the day.

The acknowledged medallists of the projectile world are the fungi. The mushrooms and toadstools that we typically think of when we talk about 'fungi' are actually just the fruiting bodies of a much larger, subterranean filamentous network – the mycelium. When conditions are suitable, this mycelium sends up a fruiting body, replete with thousands of spores. Since fungi do not move, they have evolved diverse mechanisms to distribute these spores as far as they can – often hurling them upwards to catch air currents which aid dispersal. The range of strategies they use for this is spectacular, but the self-declared gold medallist of this particular competition is the Artillery fungus, *Sphaerobolus*. These otherwise nondescript organisms, which live in decaying wood, develop spores inside a tough spore case, about a millimetre in diameter. Once mature, this entire spore 'cannonball' is ejected at speeds of over 20mph, achieving distances of up to 6m. For comparison, human shotput competitors would need to achieve distances in excess of a kilometre to come anywhere close to this!

## Extreme Achievers

Our final category in this tour of microbial athletes brings us to a class that (happily!) does not have a parallel in the human Olympics – the death-defiers and the death dealers.

Proudly perched on top of the podium in the first category is *Deinococcus radiodurans*. This otherwise nondescript bacterium is an extremophile – a microbe that thrives under extreme environments. In the case of *Deinoococcus*, the more extreme they are, the better. It is able to survive strong acids, freezing temperatures and even strong acids. But its most famous trick is to shrug off otherwise lethal doses of radiation. In fact, *Deinococcus* remains untouched by a radiation dose of 5000 Grays – a thousand times more radiation than the dose needed to kill a human.

But perhaps the most sobering microbial world record concerns not their ability to survive, but their ability to kill. Microbes are integral to life – they sit at the base of the food chain, they shape our ecosystems and the air we breathe, and they influence everything from our digestive processes to the health of our skin. However, a small number of microbial species share the dubious world-record of having wiped out more humans than any other single cause.

It is impossible to know much about lethal human infections from the time before recorded history, but if we consider this final and rather macabre competition as running for the last two thousand years, then in third place would be that familiar foe, Influenza. Globally, the 'flu virus causes numerous human deaths each year, but a major 'flu pandemic can produce record-breaking mortality – most notably the 'Spanish flu' outbreak of 1918-20, with an estimated global death toll of 40-50 million people, or 2-3% of the human population at the time.

Nudging ahead for the silver medal is another virus; smallpox. A major killer of humans for pretty much all of our history, the global migration of humans following the 'discovery' of the New World by Europeans in the 1500s led to a spectacular epidemic of this disease and an estimated 50 million deaths. Rather more positively, smallpox is also a record holder for another reason, since it remains the only human disease that has been totally eradicated by vaccination.

But the surprise winner clutching gold on the podium is not a virus, but a bacterium. *Yersinia pestis*, the bubonic plague bacterium, has ravaged human civilisation for well over a millennium. It is impossible to know how many lives it has claimed over this time, but the infamous 'Black Death' pandemic of the middle ages is estimated to have killed 200 million people worldwide; perhaps as many as half the world's population at the time. An astonishing, terrifying and undoubtedly record-breaking feat on which to end our Microbial Olympic Games.



## References and Further Reading


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