Hosts and pathogens: war without end

Theodosius Dobzhansky once famously remarked that “nothing in biology makes sense except in the light of evolution”. Nowhere is this truer than in the never ending struggle between animals and the pathogens (viruses, bacteria and parasites) which attack them. Disease causing microorganisms are, of course, not evil monsters; instead they are much like you and me. All they want is enough to eat and a bit of peace and quiet so they can raise a brood of baby pathogens. The trouble is that they have chosen us as food. This leads to an endless struggle in which the pathogens are constantly trying to break through our defences while we are constantly trying to stop this happening.

In this endless struggle animals have evolved a range of highly effective destructive systems that are, in principle, well able to destroy any pathogen. However these systems can also destroy our own tissues and so, as with any defence system, immunity has to have a means of distinguishing “friend” from “foe”. The number of possible different pathogens which might arise is essentially infinite and so we cannot make one specific receptor to detect each possible pathogen. In fact since we, like most other complex animals, only possess around 20,000 genes, only a few genes can be exclusively devoted to the construction of our immune system. The trick used is that our few immune receptors have been naturally selected to be directed against structures which are common to many microorganisms but are not present on animal cells. Each of them can thus identify hundreds of thousands of different microorganism and in this way a small repertoire of anti-pathogen receptors can function effectively as a discriminator between “friend” and “foe”. This strategy works well but of course the danger is always that a new pathogen arises which is able to avoid detection by this small receptor array.

A tiny group of animals – the vertebrates - has devised an additional way of doing things. This involves a new cell type – the lymphocytes. These cells express a novel type of immune receptor whose genes are mutated at such an extraordinary rate that every newly formed lymphocyte bears a different mutant receptor. The number of different such receptors which can be formed is probably in excess of 10^{14} (10^{14} is a 1 with fourteen nothings after it) and thus is so large that it can recognise essentially everything.

These lymphocyte receptors have given vertebrates an enormous advantage in the struggle against pathogens, but they are far from being a game-changing knock out blow. Evolutionary pressure ensures that some pathogens will always find a way to get around them (HIV is a good example). Nevertheless understanding how this system evolved and how it is currently regulated are among the most fascinating, though as yet incompletely understood, stories in bio-medicine.

The immune system has been moulded by evolution and it provides the population with an effective defence system. “Survival of the fittest” is the old slogan and it emphasises the advantages that a genetically diverse population has. For the individual, however, all that matters is whether one ends up as a survivor or amongst the dead. The alternative slogan, “survival of the survivors”,

emphasises instead that genes are not the only option and that if one is smart or lucky then one can squeeze out an extra little advantage. Currently there are only two ways to help tip the balance in your favour – antimicrobials and vaccination. A better understanding of how the immune system evolved may provide us with more options.

Robert S Jack
University of Greifswald, Department of Immunology, Greifswald, Germany

Publication

Evolution of Immunity and Pathogens.
Jack RS
Results Probl Cell Differ. 2015