Parasites: Friends Without Benefits (Part 1)

The following is a rough transcript of a talk by Peter O'Donoghue (POD) at a parasitology outreach event, Science in the Pub. Peter points out that this was a social interactive occasion not a bonafide scientific discourse - so many liberties were therefore taken with content and language in the pursuit of entertainment, somewhat in the vein of Mark Twain's famous quip "Get your facts first, then distort them as you please!"

Opening refrain: "Nobody loves me, everybody hates me, I think I'll go and eat some worms,

big worms, round worms, fat worms, skinny worms, worms that squiggle and squirm,

bite their heads off, suck their guts out, throw their skins away,

nobody loves me, everybody hates me, I think I'll eat worms today"

Guess what the topic of today's talk is? Yes, worms – or more accurately, PARASITES! It is fortuitous having this meeting in a pub. A very old joke epitomizes the association. In the 40's, a temperance worker tried to show the audience the evils of demon drink by placing an earthworm in a glass of water (where it wriggled happily) and then in a glass of whisky (where it died). She asked "What does this show you?" A drunken voice from the back row shouted out "That drinking whisky will cure your worms!" So, ladies and gentlemen, I propose a toast "To the anthelmintic properties of alcohol!"

So, what is PARASITOLOGY? Over the years, I have received some very weird letters addressed to:

- Department of Para-cytology (I don't study pap smears);
- Department of Para-psychology (I don't study poltergeists or evil spirits);
- Department of Para-shitology (close enough – they got the medium right) if we drop the 'H', we get
- Department of Parasitology (the study of parasites – nasty critters living at the expense of others)

The term 'parasite' is well known in society as a colloquialism for "bludger', 'leech' or 'sycophant' and is often used to describe politicians, bureaucrats, spouses, children, etc. In biology, parasitism turns out to be the most common way of life! Nearly every aquatic or terrestrial organism has a parasite or two. Parasites rule! Let's examine some core concepts or basic ideas central to parasitology.

1

Parasites are friends without benefits!

All parasites use a host for all or some of their life-cycle, and by definition, cause harm to their hosts. Many other organisms also live in association with hosts. The broad term for organisms that live in association with hosts is symbiosis.

Parasites: Friends Without Benefits continued

Symbiotes include:

- mutualists, which benefit their hosts (e.g. rumen protozoa contributing to fermentative digestion in herbivores);
- commensals, which give no benefit but cause no harm (e.g. various lumen-dwelling organisms live in the intestines of vertebrates but have not been associated with any pathology); and
- parasites, which cause harm to their hosts (e.g. helminth and protozoan endoparasites and arthropod ectoparasites causing host pathology).

Parasitologists themselves are quirky creatures – they work on strange critters which cause nasty diseases. They are quick to sensationalize their craft – often showing the most horrendous gory images of people and animals suffering the devastations and deprivations of parasites (deformities, lesions, death). Lucky we do not have PowerPoint today!

In reality, we have to qualify what we mean by harm – is the damage caused severe enough for the host to notice it as disease? All parasites cause structural and functional losses to the host by destroying cells. If the infection is light and only a few cells are lost, the host may not even notice. If the infection is heavy and many cells are lost, the host does notice something is wrong as clinical signs become apparent. Epidemiologically, those afflicted with clinical disease often represent the tip of the infection-iceberg, involving the few individuals with heavy severe infections that get very ill and present to a clinician (doctor or veterinarian). Many others may be infected but do not exhibit clinical signs – they represent the subclinical or asymptomatic majority. They cannot be ignored in control programs, because even though they are not sick, they are still carriers or reservoirs of infection. This brings us to the second concept.

2

The pathology of parasitism is cumulative!

The severity of disease is often correlated to the intensity of infection - the more parasites you have, the more damage they do, and the worse the disease. We recognize two main types of parasitic diseases; those caused by microparasites and those by macroparasites.

- Micro-parasites are small single-celled organisms, like protozoa, but even including bacteria and viruses. These organisms have fast life-cycles and huge multiplicative potential – they multiply rapidly in host tissues and cause acute transient diseases that may become severe and life-threatening.
- Macro-parasites are larger multicellular organisms, like worms and arthropods. They have slower longer developmental cycles. They are not multiplicative, but cumulative in the host (eat one worm egg, get one worm; eat 50 worms eggs, get 50 worms). They cause chronic persistent diseases that worsen with time.

3

Parasites exhibit tissue tropism!

All parasites have specific requirements for survival, growth and reproduction. They show strong predilections or preferences for specific host tissues, which in turn determines the types of disease that are caused. There are essentially three main sites of infection:

- gastro-intestinal tract (i.e. mouth to bum tube) – we shove food into one end and waste products come out the other. Infections cause gi disturbances, manifest by regurgitation (upchuck or vomiting) or diarrhoea (the squirts).
- circulatory system (i.e. arteries, capillaries, veins) – blood streams around the body delivering oxygen and glucose and removing carbon dioxide and metabolites. Blood parasites compromise these functions by destroying blood cells (anaemia) or blocking blood vessels (ischaemia).
- solid organs as well as tissue systems (e.g. heart, lungs, liver, brain, muscles, etc.) – parasites may migrate through, or lodge in, host tissues causing lesions and malfunction.

A crucial indicator of tissue infection is that of inflammation. Ancient Greek physicians recognized the cardinal signs of inflammation as rubor (redness), calor (heat), tumor (swelling) and dolor (pain); all caused by increased blood flow to affected tissues in an innate immune attempt to deliver bountiful phagocytes (mainly neutrophils) to the site of infection. Inflammation is indicated by the '–itis' postfix to the organ name (e.g. hepat-itis for inflammation of liver, encephal-itis in brain, card-itis in heart, etc). This brings us to a conundrum. How do infections get from one host to another in order to complete their life-cycles and perpetuate their existence?

To be contined...

Previous page: *Profs, Pints and Parasites. Friends Without Benefits* was held on Tuesday 27th August 2013, at the Aviary Rooftop Bar in Perth. This inspiring and energetic event was hosted by Renae Sayers (left) from Scitech and featured Peter O'Donoghue (right) of The University of Queensland and Stephanie Godfrey (centre) of Murdoch University.

Parasites: Friends Without Benefits (Part 2)

We continue the transcript of Peter O'Donoghue 2013 parasitology outreach event, Science in the Pub, a social interactive occasion where (POD points out) many liberties were taken with content and language in the pursuit of entertainment,

In part 1, we described three core concepts of parasitolofy:

1. Parasites are friends without benefits!
2. The pathology of parasitism is cumulative.
3. Parasites exhibit tissue tropism.

Here are some more...

4

Parasites undergo cyclic transmission between hosts!

Infected hosts act as sources of infection for other individuals in the population. Various modes of transmission have been identified, each being particularly suited to parasites from different body compartments. Ask yourself the following questions!

- **How do parasites get from the gut of one host to the gut of another?** Many enteric parasites use faecal-oral transmission strategies whereby environmentally resistant cysts or eggs survive outside their hosts and contaminate food and water supplies (so do not eat poo!).
- **How do parasites get from the blood of one host to the blood of another?** Many blood parasites use haematophagous (blood-sucking) arthropods as vectors or transport hosts to journey between individuals (so don't get bitten!).
- **How do parasites get from the internal organs of one host to those of another?** Many tissue parasites undergo predator-prey transmission whereby encysted stages in the tissues of prey animals are eaten by predators which then produce cysts or eggs to contaminate prey food supplies (so as a predator, do not eat raw meat!).

There are some variations on these themes:

- **How do parasites get from the urogenital tract of one host to that of another?** Some parasites do not form resistant stages but rely on intimate body contact between hosts for their transmission; such as occurs during sex (venereal transmission) (so do not have sex!).
- **How do parasites get from infected mothers to their babies?** Regrettably, some parasites may cross the placenta during pregnancy and infect the developing foetus, often with disastrous consequences (so do not get pregnant!). Alternatively, some parasites may be transmitted through the mother's milk when the newborn suckles (so do not breast-feed!).

Transplacental and transmammary transmission are forms of vertical transmission as the parasites are passed between different host generations, whereas all other types of transmission are referred to as horizontal transmission as the parasites are usually passed between individuals of the same host generation. Understanding parasite modes of transmission is central to effective control. So is an understanding of the different patterns of infection.

5

Parasites discriminate!

Infections are not uniformly distributed throughout populations. Most individuals have few parasites, while a few individuals have most parasites. - This is known as overdispersion or aggregated distribution [this guy in the front row may have 1,000 worms while the rest of us have only one or none - Why is it so? Greed, avarice, bad luck? Or does he demonstrate some predisposing behaviour (poor hygiene, nail-biter, night-soil gardener, ravenous carnivore, etc.). He should drink more anthelmintic! – A toast then, to the few among us with the most passengers.

Overdispersion may mean that the prevalence of infection is low (small number of individuals infected at any one time), but over time, infections may resolve and new individuals become infected. The incidence of infection (that is, the change in prevalence) may wax and wane, but eventually many individuals may have been exposed and infected. This would account for the high seroprevalence found in many populations; that is, the number of individuals found with antibodies against parasites, if not parasites themselves (remember that antibodies may persist for years after the infection has resolved).

People also vary in their susceptibility to infection:

- by age (the very young and very old are more susceptible presumably due to their developing or senescent immune systems);
- by nutritional status (malnourished and 'stressed' individuals are more susceptible);

- by immune status (some people are born with congenital immuno-deficiencies while others acquire immuno-deficiencies due to infection (e.g. HIV-AIDS) or treatment (immuno-suppressive chemotherapy due to cancer or transplantation); and also
- by gender (yes, females may be more susceptible to parasites – why?). When women become pregnant, they are carrying a foetus that is half-self and half-nonself, so they undergo partial immunosuppression to avoid rejecting the foetus, but this makes them more susceptible to infections - for example, most of the one million deaths due to malaria each year are pregnant women and very young children.

Some parasites even prefer female hosts.

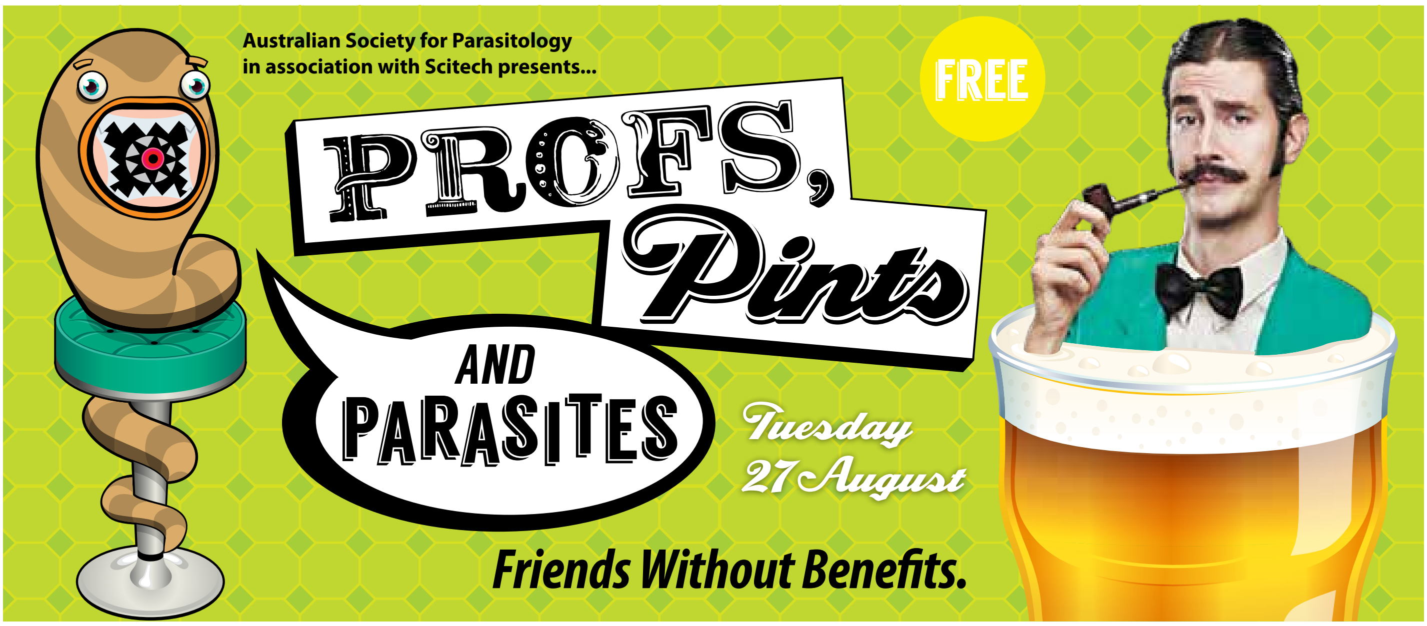
- Head lice prefer girls (who have clean hair and huddle together in schoolyards in groups, while the dirty-haired boys are running amok in the playground)
- Women suffer urogenital problems with Trichomonas infections while males are mostly asymptomatic carriers (the parasites like the environment of the vagina and uterus, which men lack!).
- Vertical transmission will only occur between females and their offspring (because the parasites either cross the placenta during pregnancy or are transmitted in mother's milk during lactation - males get off scot-free because, yes you guessed it, they do not have wombs or breasts).

Parasites themselves even display a marked gender inequity:

- Many parasites exhibit marked sexual dimorphism, that is, males and females are built differently. In most cases, the female parasites are bigger, better, live longer, feed more and cause more problems.
- Parasite sex can be a rough encounter. Some male worms have spicules which are spikes used to stab the female during coitus to hang on. Some male arthropods are just little guys, little packets of sperm, so they need to get in and get out quickly to avoid an unhappy ending.
- Some parasites have even learnt a cute trick. The females can do without males and have babies without mating. This is known as parthenogenesis (often a form of male redundancy).
- Other parasites have become quite hedonistic, and have both male and female reproductive organs. These hermaphrodites can cross-fertilize as well as self-fertilize (they literally can do themselves).
- There has recently been some interesting work on bacterial infections in ectoparasites such as mosquitoes. Infections by the bacterium Wohlbachia exert some strange effects on males: they can selectively kill males (murderers!), selectively sterilize males (emasculators!), or induce male feminization (turning the guys into girls). Scary concepts!

Given the extraordinary range of ways parasites and hosts come together and the possible devastating consequences of infections, we need to have very good methods for detecting infections in the first place.

A flyer for the original Inspiring Australia funded joint ASP and SciTech talk in August 2013



6

Differential diagnosis is difficult!

Usually, you cannot diagnose parasitic infections on the basis of disease presentation (symptomatology) because most clinical symptoms (described to clinician) and signs (observed y clinician) are vague and nonspecific – other infectious agents such as viruses, bacteria, and fungi may have caused them. Looking specifically for clinical features also does not allow the detection of subclinical or asymptomatic infections (because these hosts often do not know they are infected). To definitively diagnose parasitic infections, we need to either:

- directly detect parasites in host samples or
- find clear indirect evidence of their presence (such as specific host antibodies)

Many techniques have been developed to find parasite developmental stages in clinical samples. Macroscopic and microscopic techniques have been developed so we can see parasites in host samples (WYSIWYG = what you see is what you got/get). This requires a basic understanding of parasite life-cycles. There may be few adult parasites present, but they could be hundreds or thousands of eggs or larval offspring present. These developmental stages are often in high abundance, due to the need for many parasites to have high numbers of offspring as many will not be successfully transmitted to another host and will die. For example, Ascaris worms lay thousands of eggs each day which are released in host faeces. It was once estimated that if we piled all the eggs laid in one year by female Ascaris worms, the pile would be bigger than Mount Everest. Of course, not all of those eggs will be ingested and result in infections. Most parasites need to be very fecund to ensure a few survive and lead to propagation of the species. Their transmission patterns could be considered wasteful, but they are still eminently successful as evidenced by the survival and prevalence of parasites in the world.

Looking directly at live parasites also gives us a greater appreciation for their motility. Parasites are generally not slow lumbering beasts, in fact, most exhibit quick furtive movement. They have high metabolic demands and are voracious in order to get enough energy to move, grow and divide. Let us look at parasite movement through interpretive dance:

- amoebae (pseudopodia) creepy crawlers (do softshoe shuffle) using rolling adhesion and microtubules, also exhibit phagocytosis (same processes used by macrophages)
- flagellates (flagella) swimmers, either anterior flagella used as helicopter propellers to pull body forward (do swimming motion) or recurrent flagella used as tail to push body forward (do tail fan) – some even have an attached undulating membrane which functions like the dorsal fin on fish (poor confused trypanosomes have undulating membrane and flagellum but use it in reverse)
- ciliates (cilia) swimmers, multiple hair-like extensions of cell membrane used to swim (do jazz-hands), need good coordination to produce synchronous waves (cross arms and do jazz hands)
- apicomplexa (known for forming spores rather than motility), have anterior apical complex used to facilitate entry in host cells by releasing chemicals (play peek-a-boo and spit)
- nematodes (tubes under pressure with longitudinal bands of muscle) thrashers (do sideways shaking motion) like a punk rave or more sophisticated like Beyonce dance
- cestodes and trematodes (flat bodies with 3D arrays of muscles) squirmers showing exquisite body motion (do writhing ecstatic movement) like sensual seducer/seductress – who are they seducing – they are all hermaphrodites – "Who's a pretty boy? I am! Who's a gorgeous girl? I am too!"
- ticks, mites, lice (cryptic sneaky walkers) move through hair, fur, feathers looking for a good spot to feed and lay eggs (do sneaky stealthy walk through forest) head lice got it easy through forest of upstanding hairs while pubic lice struggle with curly thickets
- fleas (jumpers) compressed resilin pads held under pressure, released when host nearby (do standing jump) definitely not superman!
- flies (fliers) many with wings to find hosts (do butterfly wing dance), but larvae are creepy crawling maggots that breathe through their butts (show butt to audience and extrude two fingers)

Combine it all for new dance sensation ("Prancing Parasites") (amoebae creeping – flagellates swimming – ciliates rowing – apicomplexa invading – nematodes thrashing – cestodes squirming – ticks questing – fleas leaping – flies flying – maggots breathing)

As laboratories became more advanced, many techniques have been developed to provide indirect evidence of the presence of parasites.

- In particular, numerous immunoserological tests have been developed to test host blood samples for specific antibodies against parasite antigens. The tests have fancy acronyms, such as CFT

Parasites: Friends Without Benefits continued

(complement fixation test), IHAT (indirect haemagglutination test), IFAT (indirect fluorescent antibody test) and ELISA (enzyme-linked immunosorbent assay) and many commercial, test kits are now available. These tests must have good sensitivity and specificity so they do not generate too many false positive or false negative results (with may have disastrous consequences).

- More recently, the molecular biological revolution has generated quite sophisticated techniques to detect parasite proteins or parasite DNA in host samples. Infections can be detected in fresh samples, not so fresh samples and even old museum samples using some techniques. You are not even looking for whole parasites, just some molecules. Whole new fields of study have been opened up by such techniques and we now have many laboratories specializing in molecular detection, molecular epidemiology, and molecular phylogeny.

So what samples are examined? (my wife says I am the master of inappropriate dinner-table conversation)

- faeces (science called coprology) (samples sometimes collected by digital stimulation of anal sphincter – any volunteers?)

- blood (humans are quite accustomed to providing blood samples, but you should try to bleed a snake, lizard, bird, elephant?)

- tissues (ante-mortem biopsies – lump-ectomies)(post-mortem autopsies – take what you want)

(where do you get bodies – roadkill, cull, shoot...)

Here are some samples I prepared earlier: a tube of blood (actually tomato juice), a container of faeces (actually brown salsa) and a jar of tissue cysts (actually pickled antipasto). You need to use all your senses to examine the matrix under test:

- look at it (sight) – what does it look like, colour, consistency, content

- listen to it (sound) – shake the tube and listen for sloppiness –pertinent to hydration, volume/weight

- sniff it (smell) – does it have a distinctive odour – some swear they can diagnose giardiasis and cryptosporidiosis by the faecal aroma (like curdled milk)

- handle it (touch) – is it soft, hard, slimy, lumpy, smooth, rough

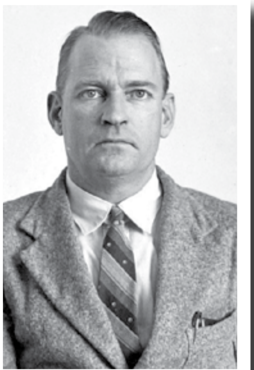
- put it on your tongue (taste) – does it have a distinctive taste – acidic, sour, sweet, spicy! YUM!!!

[years ago midwives used to lick newborn baby's skin to test saltiness (indicative of cystic fibrosis) and taste newborn baby's urine to test sweetness (indicative of diabetes)]

Having diagnosed an infection, what are you going to do about it? ***To be continued***

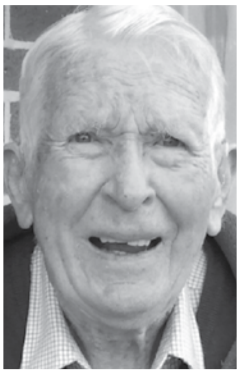
Fellows of the Society: names to the faces

Here are the names of the five ASP Fellows shown on page 13



Bob Roberts
FASP 1967

Ian Mackerras
FASP 1976



Bill Southcott
FASP 1983

Klaus Rohde
FASP 1989

Dave Spratt
FASP 2000

To read a brief biography of each Fellow, visit
parasite.org.au/the-society/fellows-of-the-society/

Parasites: Friends Without Benefits (Part 3)

We continue the transcript of Peter O'Donoghue 2013 parasitology outreach event, Science in the Pub, a social interactive occasion where (POD points out) many liberties were taken with content and language in the pursuit of entertainment,

In part 1 and 2, we described six core concepts of parasitology:

1. Parasites are friends without benefits!
2. The pathology of parasitism is cumulative.
3. Parasites exhibit tissue tropism.
4. Parasites undergo cyclic transmission between hosts!
5. Parasites discriminate!
6. Differential diagnosis is difficult!

Here are some more...

7

Parasites are hard to control

Why? There are profound problems with each of the 3 control strategies.

Drug treatment (including chemotherapy to cure you after infection as well as chemoprophylaxis to prevent infections). Many drugs have been developed from plant extracts (logical as many plants have good chemical defences against parasites). However, the booming pharmaceutical industry of decades past is now restricted by fierce competition, smaller profit margins and dwindling discoveries. Over-use and under-dosing have also provided many opportunities for parasites to experience sub-lethal drug concentrations and drug resistance is becoming widespread.

Vaccination (including anti-infection, anti-disease, and anti-transmission vaccines). There are many success stories for vaccines developed against diseases caused by bacteria and viruses, but few for those caused by the relatively more complex eukaryotic protozoa, helminths or arthropods (which infect other eukaryotes). In many cases, we do not know how the host-parasite immunological interactions work to provide protection, but they must be good as we are not all dying of parasitic diseases. Many parasitic diseases are self-limiting and moderated by host immune responses. There are even cases of premunitive (or concomitant) immunity whereby hosts harbour a few live parasites but are protected against subsequent super-infections (this is in contrast to sterile immunity whereby the pathogens are eradicated from the host). A good balance between parasite virulence and host immunity (the quintessential evolutionary arms race) is sometimes achieved as a state of enzootic stability (where neither host nor parasite is eliminated). There are a few success stories for anti-parasite vaccines which gives us hope for the future (e.g. irradiated lungworm larvae, coccidia vaccines, cysticercus oncosphere antigens).

Environmental management (any strategy designed to break the transmission cycle). There are many things that can be done to stop parasite transmission by changing the physical environment, changing processes and behaviours, and controlling biological entities (notably vectors). Huge advances have been made in disease control through water treatment, sewage treatment, improved hygiene, food inspection and preservation; particularly since urbanization where humans have become crowded into cities (formerly known as pest-holes of disease but still experiencing problems with urban ghettos, poverty, inadequate infrastructures, refugees and illegal residents). In many areas, social behaviours still persist which are highly conducive to parasite transmission: such as the use of night soil (faces and urine collected overnight) to fertilize vegetable crops (despite more than adequate biocomposting processes), the preference for raw or rare meats by many groups (propagated by TV lifestyle/cooking shows) and even weird alternative medicines (such as frog poultices for wounds). It seems the hardest thing to do is to change human behaviour. We should all be able to:

- avoid coprophagy (do not eat poo) (thus breaking faecal-oral transmission)
- avoid haematophagy (do not get bitten) (thus breaking vector-borne transmission)
- undertake sensible zoophagy (cook food) (thus breaking predator-prey transmission)
- practice safe sex (use protection) (thus breaking venereal transmission)
- institute antenatal screening (thus reducing the risks of congenital transmission).

8

Parasite biodiversity is vast

It is very hard to estimate the total number of parasites species on planet Earth, considering we are still discovering them, many host species have yet to be examined, and there is no central data base. Nevertheless, it has been estimated that there are some 6 million parasite species in total, almost 1,000 species have been recorded in humans. Where do they all come from? If men are from

Parasites: Friends Without Benefits continued

Mars, and women are from Venus, where are parasites from? It is a brilliant time of discovery, and has been for the last century. We have exquisite techniques to detect and describe parasites and the taxonomic game is played by many. We have:

- splitters (identifying new species on the basis of minor differences),
- lumpers (collapsing species into single entities on the disbelief of their differences),
- voyeurs (spending their entire lives describing the genitalia of some obscure group of worms),
- empiricists (relying on experience)
- rationalists (relying on reasoning),
- alpha-numerical taxonomists (a dying breed who rely on size and appearance of a constellation of characters), and now
- molecular gel jockeys (who don't need to see whole parasites, just partial gene sequences to identify clades, groups, species, subspecies, strains, clones, lines, stocks)

Many strange names have emerged, although it is considered bad form to name them after yourself, but OK to name them after a friend, colleague or enemy. Who can ever forget Eutetrarhynchus odonoghuei, a tapeworm of sharks – distinguished by the presence of multiple testes (I don't know whether to be flattered or annoyed by this honour, because all other species named in the paper had more testes). One thing we all agree on is the basic zoological division of parasitology into 3 main assemblages:

- single-celled parasites (protozoa)
- riggly worms (helminths)
- biting bugs (arthropods)

To be continued

Parasites: Friends Without Benefits (Part 4)

We continuethe transcript of Peter O'Donoghue 2013 parasitology outreach event, Science in the Pub, a social interactive occasion where (POD points out) many liberties were taken with content and language in the pursuit of entertainment,

In part 1 to 3, we described eight core concepts of parasitology:

1. Parasites are friends without benefits!
2. The pathology of parasitism is cumulative.
3. Parasites exhibit tissue tropism.
4. Parasites undergo cyclic transmission between hosts!
5. Parasites discriminate!
6. Differential diagnosis is difficult!
7. Parasites are hard to control
8. Parasite biodiversity is vast

In this penultimate episode, POD's talk takes a taxonomic turn.

9

Rogue's gallery

PROTOZOA

Four groups are recognized on basis of their motility (or lack of)

- cells that creep and crawl (amoebae sliding over substrates, such as gut lining) - many free-living species, good guys in water and soil as they eat bacteria and algae; some parasites

- cells with propellers (flagellates swimming in body fluids, gut content, blood) - many free-living in water, some symbiotes (esp. in termites), some parasitic in gut and blood

- cells with numerous oars (ciliates swimming in fluids) - many free-living species, many mutualists/symbiotes, esp. in herbivores

- cells that just sit there (spore-forming sporozoa) all parasites, must invade host cells to form spores

Protozoan life-cycles essentially involve an endogenous feeding stages (a trophozoite) in the host, and a resistant stage formed as a transmission strategy (a cyst or oocyst passed into the external environment or a spore formed in another host).

Amoeba [trophozoites crawling over substrates using false-feet (= pseudopodia) – motility involves transient microtubular organization and protoplasmic streaming - essential the same as the motion observed with human macrophages (an example of conservation in Nature)]

- *Entamoeba* causing amoebic dysentery, extraintestinal lesions, abscesses in soft tissues, such as liver/brain, anchovy sauce pus (never let the sun set on undrained pus!)

- *Acanthamoeba* causing keratitis, contact lenses (soft/hard) washed in contaminated water

Flagellates [trophozoites swimming in body fluids, using elongate flagella (with 2+9 microtubule cores) - flagellar motion involves dynein-walking mechanism producing undulating motion (hence flagella sometimes called undulopodia), quite different from the helical/spiral flagellar motion of bacteria]

- *Trichomonas* causing vaginitis/ infertility, direct venereal transmission, chronic inflammation linked to cervical cancer, infections in cattle transmitted by AI (cryopreservation allows flagellated sperm, and flagellated protozoa, to survive (controlled by culling – kill the bulls)

- *Giardia* causing watery diarrhoea (Delhi belly, Bali belly, porcelain polka, the trots, the squirts), amazing looking parasites, bilateral symmetry, eyes looking back at you, sucker for attachment, failure-to-thrive syndrome, treatment with metronidazole (nasty side-effects with alcohol)

- Trypanosomes causing sleeping sickness/Chagas disease/kala azar, trypomastigotes swimming in vertebrate blood and/or amastigotes forming cysts in vertebrate tissues, promastigotes/epimastigotes formed in vectors (tsetse flies for sleeping sickness caused by *Trypanosoma brucei*; reduviid bugs for Chagas disease caused by *Trypanosoma cruzi*; sand-flies for kala azar caused by *Leishmania* spp.)

Ciliates [trophozoites swim in body fluids using numerous undulipodia, similar in ultrastructure to flagella but having complex interconnections to facilitate synchronous movement]

- *Balantidium* causing bloody diarrhoea, also pig-pen breath associated with vented aromatic ester

Sporozoa [spore-formers, invade host cells, multiply and form more spores for transmission by faecal-oral, vector-borne or predator-prey routes]

- *Eimeria/Isospora* causing coccidiosis (diarrhoea), enteric coccidia, monoxenous, fast life cycles, faecal-oral transmission of oocysts

- *Toxoplasma* causing toxoplasmosis (space-occupying lesions), tissue-cyst-forming coccidia, heteroxenous, slow life cycles, predator-prey transmission, definitive hosts are cats, intermediate hosts are any other vertebrate, infections during pregnancy can cause abortion, still-birth, congenital abnormalities, females infected before pregnancy transfer their immunity to their offspring, so ladies, get infected (eat raw meat or cat poo before family planning).

- *Plasmodium* causing malaria in humans, one of the Great Fevers plaguing human history, haemosporidian, parasites replicate in liver then cycle through ring stages, trophozoites, schizonts and merozoites in red blood cells (causing haemolytic anaemia and ischaemia), typically forming toxic haemozoin pigment (parasite poop comprised of metabolized haemoglobin), transmitted by mosquitoes (females requiring blood meal)

- *Babesia* causing babesiosis (tick fever) in animals, piroplasm parasites replicate in red blood cells (causing haemolytic anaemia and jaundice), transmitted by ticks, including one-host ticks in which transovarian transmission occurs)

- *Enterocytozoon* causing diarrhoea in immunocompromised patients, microsporan parasites now shown to be a fungus, other species common in fish and shellfish, how did they get to humans?

- *Henneguya* causing lesions in fish, myxozoan parasites now shown to be cnidaria (similar to jellyfish), occasionally detected as pseudo-parasites in humans, including sperm-like spores in faeces and accusations of sexual abuse

HELMINTHS

Three main groups of worms (really original names, based on shape)

- nematodes (called roundworms because they are round in cross-section)

- cestodes (called tapeworms because they are flattened like tape)

- trematodes (called flatworms or flukes because they are flattened like leaves)

Helminth life-cycles essentially involve three stages, eggs which hatch to release larvae which moult several times into adults. Life-cycles are completed by faecal-oral transmission of eggs or larvae, vector-borne transmission of larvae, or predator-prey transmission of encysted larvae.

Nemathelminthes (nematodes) are often referred to as tubes under pressure, they are pseudocoelomate and their fluid-filled body cavities act as hydrostatic skeletons, they have prominent longitudinal muscles which produce a sideways thrashing motion

- pinworms (*Enterobius)*, stuff of legends (oldwives tales) females come out anus at night-time and glue eggs around anus, produce very itchy bottom and irritability

- whipworms (*Trichuris*), eggs passed in faeces, ingested with contaminated food/water, adult worms live half buried in rectal wall, trick host into thinking there are some faeces to void (called tenesmus), over-straining may cause rectal prolapse

- roundworms (*Ascaris*), eggs passed in faeces, ingested with contaminated food/water, larvae in gut then undergo curious pulmonary migration, penetrate gut, carried to lungs in blood, break into alveoli, coughed up, swallowed, back in gut (WHERE THEY STARTED)!!! tangles of worms in gut cause obstructions, watch what you do with nightsoil!

- hookworms (*Ancylostoma*), adults feed on blood, bite gut mucosa, eggs passed in faeces but hatch externally, release larvae which then invade host through skin (transdermal migration) causing subcutaneous larval migrans, resolves spontaneously by larvae undergo pulmonary migration to end up in gut to suck blood – best control programs involved building toilets, and getting children to wear shoes

- filarial worms (*Onchocerca, Wuchereria*), transmitted by vectors (flies and mosquitoes) which pick larval microfilariae in blood/tissues, adult worms live in nodules – females are huge - control may involve nodule-ctomy (surgical removal of females) - new drug (rutin) used to help drain lymphatics (so treatment for organ enlargement = rutin)

Platyhelminthes are acoelomate flatworms, they do not have body cavities and have flattened bodies so that nutrients can reach all tissues. They include the cestodes (elongate tapeworms) and the trematodes (leaf-like flukes). They have longitudinal, transverse and circular muscles and exhibit exquisite 3-D writhing motion.

Cyclophyllidean cestodes utilize terrestrial animals as definitive and intermediate hosts, and the adult worms have a prominent anterior scolex (often with suckers and sometimes armed with hooks)

- *Taenia* tapeworms cause cysticercosis in domestic animals. The adult worms actually live in humans but the larval stages (metacestodes) become encysted in the tissues of cattle and pigs.

- *Echinococcus* causes hydatid disease in humans. The adult worms actually live in dogs but the larval stages form large hydatid cysts in many other vertebrates, including humans.

Pseudophyllidean cestodes use terrestrial animals as definitive hosts and aquatic animals as intermediate hosts, and the adult worms have prominent anterior bothria (grooved suckers).

- *Diphyllobothrium* are human tapeworms but the larval stages occur in freshwater fish (one unusual outbreak linked to Jewish grandmothers in New York City who

Parasites: Friends Without Benefits continued

make gefilte fish delicacies)

Digenean trematodes have heteroxenous life-cycles involving hermaphroditic adults in vertebrates and asexual amplification in aquatic snails. Adult flukes may be found in the gut, liver or blood.

- *Fasciolopsis/Clonorchis* are intestinal flukes in humans who have consumed encysted metacercariae on aquatic plants or in small fish/crustacea (crabs)
- *Fasciola* are liver flukes commonly found in herbivores grazing on pastures containing encysted metacercariae. Liver disease in dairy cattle mimics the fibrotic cirrhosis found in alcoholics
- *Schistosoma* are unusual blood flukes in that the adults are not hermaphroditic but the male worms clasp a female in a special love groove (gynecophoreal canal) for their lifetime. Females lay eggs into the bloodstream and they must dissolve their way out of the host (aka ALIEN) causing a lot of pathology

ARTHROPODS

have articulated limbs and belong to three main groups:

- insects (six-legged biters)
- arachnids (eight-legged biters)
- crustacea (armoured swimmers)

All arthropods have an exoskeleton, which poses a problem for the growing animal. This is solved by the process of periodic ecdysis (moulting). Arthropod life-cycles involve eggs which hatch to release larvae which then either grow through nymph stages to adults or undergo pupation to change into adults (termed incomplete and complete metamorphosis). Parasitic representatives are ectoparasitic and may cause local/focal problems (pain, annoyance, irritation, itching, altered behaviour, trauma, dermatitis, ulceration, inflammation, allergy, hypersensitivity), systemic effects (blood-loss, anaemia, toxicoses, poisoning, paralysis), predispose to secondary infections or even act as vectors for other infectious micro-organisms.

Insects are one of the most abundant assemblages on Earth, and there are many parasitic groups, both of plants and animals.

- mosquitoes are voracious blood feeders (swarms causing anaemia), annoying pests (cause erratic behaviours), and female Anopheles transmit malaria when they inject anticoagulant saliva (also containing Plasmodium sporozoites) into humans during feeding
- flies come in many types (tsetse flies, black flies, sand flies, bot flies, etc.). Sometimes the adult fly is the parasite (sucking fluids or biting tissues using scissor action mandibles), and sometimes the larval stages are parasitic (burrowing into tissues causing myiasis (flystrike)).
- fleas are renowned for their prodigious jumping abilities using unique resilin pads held under compression. Larval stages are caterpillar-like, feeding on adult flea scat, before undergoing pupation in dens/burrows
- lice on humans may infest the head, body or pubis. Adult head lice like girls with long clean hair and drug resistance has spawned a growing alternative medicine market.
- bugs also infest human dwellings and beds. Assassin (reduviid) bugs transmit Chagas disease when they defaecate near bite sites (stercorarian transmission)

Arachnids comprise many free-living and parasitic groups, the latter being voracious feeders when infesting vertebrate hosts.

- mites are microscopic in size and often burrow into host orifices or epidermal tissues. The scabies mite Sarcoptes causes nasty lesions in the skin, particularly in geriatric communities.
- ticks are macroscopic in size and females may engorge on host blood. They are said to be 1, 2 or 3-host ticks depending on whether their larval, nymphal and adult stages feed on 1, 2 or 3 different hosts. The paralysis tick Ixodes holocyclus may cause ascending fatal paralysis in dogs or Bell’s palsy (craniofacial nerve paralysis) in young children.

Crustaceans have a crust or shell and exhibit many other unique characters to distinguish them from other arthropods. Many occur as free-living aquatic species while other are parasitic on aquatic hosts.

- copepods in freshwater bodies may harbor Dracunculus (guinea worm) larvae, but this parasite has almost been eradicated worldwide by filtering drinking water. There are few alternatives as chemotherapy may kill the metre long worms in human limbs causing anaphylaxis, and surgery cannot follow their torturous paths (folk remedy involves slowly winding them out of the skin using a twig)
- various copepods attach themselves to fish, including the anchor worm Lernaea embedded in skin
- an unusual parasite is the isopod Cymothea which invades snapper and then replaces its tongue
- another is the rhizocephalan Sacculina which infects crabs and causes parasitic castration. What is it with parasites and gonads?

The final episode of POD's talk will appear in the next newsletter.

Parasites: Friends Without Benefits (Part 5)

We conclude he transcript of Peter O'Donoghue 2013 parasitology outreach event, Science in the Pub, a social interactive occasion where (POD points out) many liberties were taken with content and language in the pursuit of entertainment,

In part 1 to 3, we described eight core concepts of parasitology:

1. Parasites are friends without benefits!
2. The pathology of parasitism is cumulative.
3. Parasites exhibit tissue tropism.
4. Parasites undergo cyclic transmission between hosts!
5. Parasites discriminate!
6. Differential diagnosis is difficult!
7. Parasites are hard to control
8. Parasite biodiversity is vast

In Part 4, POD then looked at the rogue's gallery of protozoa, helminths and arthropods.

In this last episode, POD looks for redeeming features and asks if we should actually be trying to conserve parasites.

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Redeeming features?

Well, the foregoing has all been doom and gloom, with gruesome but spectacular parasites causing infections ranging from asymptomatic to mild to severe in disease presentation. Are parasites useful for anything?

- **Weight loss**: Some 60-70 years ago, there were advertisements announcing the beneficial weight loss qualities of having your own parasites, under the endearing names of Lard-B-Gone, Taeniadex, etc. You could send away for a measured dose of parasites to consume to become infected. The adult tapeworms in your gut would compete for your nutrients and thus you would not become fat, and may even lose weight. There is so much wrong with this, I shudder. Some found that food consumption actually increased, presumably because you were now eating for two, and the worm may have stimulated your appetite.

- **Evolutionary pressure**: It is well documented in text books that there is an evolutionary arms race between the invasive capabilities of microbes and the defence capabilities of their hosts; that is, a war between parasite virulence and host immunity. We are slowly characterizing these interactions so that we can manipulate them to achieve some control by virulence mitigation, immuno-therapy, and vaccination. It is a complex multi-factorial highly integrated field. It seems that parasites are good at keeping the host immune system busy!

- **Hygiene hypothesis**: Recently, a link was made between the lower incidence of certain diseases in people with mild helminth infections. It was reasoned that worms kept the immune system busy, and when people became more hygienic and eliminated their worms, the immune system turned on itself and led to a whole series of allergic and auto-immune diseases (such as irritable bowel syndrome, Crohn’s disease, coeliac disease, ulcerative colitis, asthma, and even multiple sclerosis and diabetes). A backyard industry sprang up, where by “helminthic therapy” was offered. You could order Necator hookworm larvae to place on your skin, or Trichuris suis whipworm eggs to ingest, thus giving your immune system something to do instead of causing problems. Many people swear by it, but extreme caution is advised. The parasites used are not from clean cultures but originate from all sorts of hosts under all sorts of conditions. I would be worried about other unintended hitchhikers in the inocula (including viral and bacterial pathogens – as these worms can host microbes).

Parasites: Friends Without Benefits continued

- **Food sources**: Can you eat parasites as food items without getting infected? This begs the question, do you trust in the concept of host specificity? Humans have human parasites, cows have cow parasites, although a very small number may occur in both. Can you catch a cow parasite if you eat it? Some tribesmen harvest Monezia tapeworm segments passed in cow faeces by twirling them on a stick, washing them in low streams and roasting them over an open fire - claiming they taste like chicken!

- **Sexual selection**: Field studies have shown that many females select certain mates based on their apparent health and vigour in resisting parasitic infections, some males even have secondary characters to display their anti-parasite prowess, such as elegant plumage, body size, coat condition. This must include me, as I am very adept at resisting parasites, as evidenced by my:

- receding hairline to resist head lice; reduced muscle mass to resist muscle worms; gnarly skin to resist mites; foot odour to resist Tunga fleas, and dangly scrotum to resist parasitic castration.

11

Conservation Biology

If parasites have some uses, or until we better understand their complex interactions with their hosts, maybe we should take steps to protect parasites and stop them from becoming extinct

- People have become concerned about the conservation biology of parasites, along with mutualists and commensals. They are worried about 'co-extinction' events, where the symbiotes become extinct with their hosts. Various species of bird lice are considered to be extinct, along with their bird hosts. The guinea worm Dracunculus is considered rare and may be the next to become extinct, due principally to the efforts of humans to eradicate the worm. Only one parasite is listed on the Red List of Endangered Species: the sucking louse Haematopinus found on pygmy hogs. Various countries recognize other parasites as rare and/or threatened, including the tapeworm Dasyurotaenia from the Tasmanian devil.

- It is difficult to mount a case for the conservation of parasite species, other than the loss of biodiversity, especially since parasites are blamed for contributing to host extinctions through disease and death. We know relatively little about the significance of other symbiotes, other than by definition that mutualists benefit hosts, while commensals are neutral. Most efforts in conservation biology target host species, and by rescuing them from extinction, we will also conserve their parasites. So, should we cuddle or kill our wildlife? Let's save both hosts and parasites.

- While most scientists have no philosophical or ethical dilemmas with conservation biology, parasitologists may be a breed apart. We often joke that should a live Tasmanian tiger (thylacine) ever be discovered, a parasitologist would shoot it to harvest its parasites. Parasite preservation (in alcohol) would trump wildlife conservation. So, ladies and gentlemen, I propose a final toast:

"To parasites and their hosts – friends without benefits!"