14

A cybernetic hypothesis of periodontal disease

'In conclusion, I want,' he said
'ten thousand mixed chains of predation —
none of your simple rabbit and coyote stuff!
This ocean shall have many mouths, many palates.
  I want,
say, a hundred ways of death, and three thousand
  of regeneration —
all in technicolor naturally.'

MARK O'CONNOR[1]

In this final chapter I'd like to take you on a short journey into a realm of ideas that may seem strange or unfamiliar, and which may appear to have little or no connection with the rest of the book. But there is a connection — and there's an important difference.

Periodontal disease, as we shall see, has a place in the natural order of things: it is part of the cycle of life and death that ensures the balance of nature. Omnivores such as humans and herbivores such as sheep are affected by periodontal disease. In the 'wild' this can be expected to affect individual life expectancy and thus the composition of omnivore and herbivore populations. But it is the effect of periodontal disease on wild carnivores which will concern us here — how periodontal disease may influence carnivore numbers.

However, while nature is 'concerned' with balancing the needs of the majority, pet owners are concerned with the needs of their individual dog or cat, and want it to enjoy good health throughout its time on earth. And that, either directly or indirectly, is what this book is about. But by seeing things in a wider context, by gaining a better understanding of nature's ways, we should be able to improve the lot of individual dogs and cats.

by seeing things in a wider context, by gaining a better understanding of nature's ways, we should be able to improve the lot of individual dogs and cats.

Coming to a commitment

In August 1992 a fair proportion of the Sydney veterinary community attended a lecture I gave entitled 'Pandemic of periodontal disease: a malodorous condition' (see Chapter 2). Having drawn the vets to a contemplation of the issues, I hoped I could persuade them to assume responsibility for further research — instead they scoffed. By implication they considered the issues trivial and me absurd for thinking otherwise. While their opinions of me were bearable the thing that rankled was the imputation that periodontal disease was trivial. I was sure they were wrong, but I was unsure how to go about proving it. Gradually over the following days the outline of a plan crystallised. Instead of working on periodontal issues part time I would make a bigger commitment.

The decision made, things fell into place. Alan and Jason, my veterinary associates, undertook more of the daily work of the practice, thereby freeing me for the research effort. My lack of office skills and dread of computers posed an obstacle. Luckily Charlie Garrison and Susan Rutter, long-time clients, came to the rescue. Together we bought a second-hand computer and established an office. Soon Susan and I were hard at work gathering and sorting references. With each new clue we gained encouragement that we were on the right track — and it was far from trivial.

Periodontal disease and its consequences are extremely important. For me the main breakthrough occurred with the recognition that the disease appears to be a necessary and desirable feature of carnivore biology. At first sight it was a counter-intuitive notion — until I separated the domestic scene from the wild. In domesticity periodontal disease runs out of control — the only desirable feature being that people debate why this should be so. In healthy wild carnivores periodontal disease is absent, but when they are sick or dying the disease appears.

Things which commonly occur in nature can be said to be necessary or desirable. This applies to diseases too; without them populations of animals would run out of control, displace other species and overtake food supplies. Some diseases are sporadic and acute in their effect, suddenly killing large numbers. Others, particularly the parasitic diseases, are slower to act and only affect a few individuals.

The question arises, what is the effect of periodontal disease on wild carnivores? Does it have sporadic devastating consequences or does it act by low level retardation of populations? Or does it serve a different purpose? In the quest for meaning it appeared that periodontal disease is not a typical disease, more a potential disease. When suitable conditions arise it makes an appearance — as though it can be switched on (or more rarely switched off) according to need. Chance discovery of the following passage from an old edition of *The Children's Encyclopedia* assisted me in the quest:

> Day and night the Carnivora are playing their appointed part in keeping down numbers. They themselves are without visible foes, yet have a mysterious check on over-multiplication. All the flesh-eaters are more numerous at birth than the herb-eaters. But an unseen agency takes off cubs from every nursery, or the flesh-eaters would be too numerous, and would destroy all herb-eaters. Check and countercheck are constantly at work to maintain the balance…[2]

Could periodontal disease be the means for the 'mysterious check on over-multiplication'? Was this disease the 'unseen agency' which 'takes off cubs from every nursery'?

Formulating the cybernetic hypothesis of periodontal disease

The Children's Encyclopedia reflects a willingness to pose big questions regarding life's patterns. Adults often shy away from such lines of enquiry, but these days there is one giant theory which tackles the interconnectedness of life head on. The theory, named after the Greek earth goddess, Gaia, was first put forward by James Lovelock FRS at a 1969 scientific meeting on the origins of life on Earth. Writing in 1987, Lovelock said:

> We have since defined Gaia as a complex entity involving the Earth's biosphere, atmosphere, oceans and soil; the totality constituting a feedback or cybernetic system which seeks an optimal physical and chemical environment for life on this planet. The maintenance of relatively constant conditions by active control may be conveniently described by the term 'homoeostasis'.[3]

At first the theory was derided by leading biologists. Gradually, over a 30 year period, this opposition has changed to widespread acceptance of the predictive and explanatory powers of the theory.[4] In speaking of Gaia and food chains, James Lovelock said:

> The theory of Gaia has developed to the stage where it can now be demonstrated, with the aid of numerical models and computers, that a diverse chain of predators and prey is a stable and stronger ecosystem than a single self-contained species, or a small group of very limited mix.[5]

The similarity between James Lovelock's 'diverse chain of predators' and *The Children's Encyclopedia's* 'check and countercheck [which] are constantly at work' was unmistakable. At the same time I was steeped in periodontal disease research and puzzling over each new finding. With these ideas swirling around in my head I began to ponder how periodontal disease fitted into nature's grand design. Three concepts seemed to be important:

- First — clinical experience and the veterinary literature confirm that periodontal disease is not a trivial entity. Once periodontal disease becomes established it triggers disease in other organ systems. Disease in those systems exacerbates periodontal disease — sufferers enter a downward spiral of worsening periodontal and systemic disease.
- Second — feeding on natural foodstuffs serves to cleanse the oral cavity and thus protects a carnivore from periodontal and associated disease. By contrast a starving carnivore suffers calorie deficit and consequences of an unclean mouth.
- Third — in this age of mammals, carnivores sit, as regulators, at the top of the food chain. But regulators also need to be regulated.

When these concepts are placed in the context of Gaia planetary regulation the following equations arise:

- Plants regulate herbivores; in turn, herbivores regulate plants.
- Herbivores regulate carnivores; in turn, carnivores regulate herbivores.
- Carnivores regulate periodontal disease organisms; in turn, periodontal disease organisms regulate carnivores.

Plants <=> Herbivores <=> Carnivores <=> Periodontal disease organisms

The next step to formulation of the hypothesis occurred in a dream. I woke on Christmas morning in 1992 to find a series of propositions running through my mind. In case the ideas evaporated, I tiptoed past the Christmas stockings and committed the words to paper:

Cybernetic hypothesis of periodontal disease in mammalian carnivores

Periodontal disease is the dependable disease which modulates the effects of starvation in wild carnivore population dynamics.

- A 'feedback loop' ensures that daily chewing of raw meaty bones sanitises the oral cavity of the successful carnivore.
- Failure of the 'feedback loop' facilitates multiplication of pathogenic bacteria within plaque and the development of periodontal disease.
- Incremental losses of carnivores and herbivores are thereby facilitated.
- The populations of herbivores, carnivores and bacteria are maintained in dynamic equilibrium.

I must emphasise that this schema is not a statement of established scientific fact but a hypothesis of how balance may be maintained in nature. Some of the technical terms may be unfamiliar to you; however, they do refer to familiar situations, as I shall explain.

Feedback loops

You may be wondering why death by starvation is not the simple regulator of carnivores. While the role of starvation should be acknowledged, taken on its own it would be much too crude. Why is periodontal disease important when there are many other diseases? Once again we should not discount other diseases, but they tend to be too severe in action or too unpredictable in effect. Cybernetic systems and feedback loops tend to be subtle and predictable.

James Lovelock postulated that the Earth is akin to a giant self-regulating organism with multiple cybernetic systems involving feedback loops. He was able to demonstrate that, left to the laws of chemistry, neither the oxygen level nor the temperature of the planet would be conducive to life. Contrary to expectations, conditions have been relatively stable since the emergence of life on the planet. In order to illustrate the meaning of cybernetics — the 'branch of study which is concerned with self-regulating systems of communication and control in living organisms and machines' — Lovelock described a man on the deck of a rolling ship.[6]

A sailor struck dead does not remain upright on the deck of a ship — he falls and then rolls with the movement of the ship. By contrast a living crewman employs a complex action of muscles and bones to keep upright against the effects of the wind and rolling deck. Positioning and repositioning of muscles and bones occur in response to nervous impulses. The eyes focused on the horizon, together with the organs of balance in the ears, provide overall sensitivity regarding position in space. Located in the skin, muscles and joints are sensory nerve endings which communicate subtle changes to the brain. In response to sensory input the brain communicates with and thus controls the muscles which contract and in turn control the stance of the person.

These push/pull cycles of information and action passing through the brain are called feedback loops. At the simple level a nervous impulse is sent to a muscle giving rise to a contraction. Sensors in the muscle detect the contraction and dispatch a negative message to the brain. The brain responds by sending less impulses to the muscle — thereby damping down the contraction. Gentle regulation of action is usually the preferred option and this is enhanced by several negative feedback loops having a modulating impact on the system. For the man on the ship his stance is modulated by negative feedback loops between the brain, muscles, eyes and ears.

Absence of negative feedback or the introduction of positive feedback are further potential enhancements of living systems. Under these circumstances systems accelerate beyond the usual; for instance a mother finding superhuman strength to lift a car off her child. Ordinarily this would be an impossible task due to the negative feedback of pain and psychological signals processed by the brain. Wartime exploits provide further examples of accelerating systems, sometimes out of control. We marvel at tales of courageous conduct and at other times are saddened by atrocities. We describe those caught in harmful, out-of-control feedback loops as being caught in a vicious cycle.

For carnivores natural food provides a negative feedback effect on oral bacteria — they are scrubbed away. Absence of food and therefore absence of the negative feedback loop permit bacteria to proliferate, and periodontal disease develops. Periodontal disease leads to systemic ill health which in turn, by positive feedback, worsens periodontal disease. Carnivores caught in a vicious cycle of worsening starvation and periodontal disease lose their 'appointed part in keeping down [herbivore] numbers' and death becomes inevitable. For the individual this may seem harsh, but for others in the system, whether predators or prey, there are wider cybernetic consequences. Let us use these concepts to see how incremental regulation of a pack of wolves might occur.

Hypothetical example

Wolves living in a finite environment prey on a flock of wild sheep. Without modulating influences population size will likely lurch up and down, being determined solely by food supply. As wolf numbers increase they will eat the sheep and then, when sheep become scarce, the wolves will suffer mass starvation. A few sheep remaining in an environment relatively free of predators will in turn increase in numbers until they exceed the food supply. Starvation will ensue. Violent fluctuations suit neither wolves nor sheep — a modulating influence is required.

By adding periodontal disease to the model we increase the sensitivity of wolves to starvation. In this example there are ten wolves within a pack hierarchy. On day one they catch and eat a sheep. The wolves' hunger is satiated and their mouths are scrubbed clean of bacteria. Pack hierarchy remains intact in readiness for the next hunt. For the sheep in our story, sacrifice of one means that the other flock members will not be troubled by wolves for a couple of days. However, pressure increases as fewer sheep are now available to feed the same number of wolves.

At the next hunt perchance, one wolf is injured, is late to arrive at the kill and consequently remains hungry. For nine wolves things remain much as before. For the injured wolf the outlook changes. He suffers from hunger and is somewhat weakened. Plaque begins to accumulate on his teeth. Over the succeeding days, in the absence of food, things worsen. Periodontal organisms and toxins pass into the various organ systems of the sickening wolf. His stressed immune system exacerbates the developing periodontal disease and feeds back information to other body systems.

At all times the wolves' senses of sight, touch, smell, taste and hearing provide feedback on their position in the pecking order, their position in the environment and their relationship to their prey. Unconscious feelings of physical and immune system well-being create feedback loops within the wolves' internal environment. The nine well-fed wolves become increasingly aware that wolf number ten no longer contributes to the hunt. Rather than share the kill with him they seek to ostracise him. The sick wolf, aware of his bad breath and failing fortunes, moves away rather than endure bullying. As a lone wolf, his days become numbered.

Now let's jump ahead in time to the breeding season. Good rains and bright sunlight produce plenty of herbage. Conditions provide positive feedback to the sheep; they grow fat and many lambs are born. One wolf gives birth to a litter. At first, hunting young lambs is easy and the wolf makes plenty of milk for her cubs. By four weeks of age the cubs' erupting teeth provide an opportunity for plaque organisms. Regular chewing on lamb carcasses limits the establishment of plaque and the cubs remain healthy.

By the age of four months the dynamics begin to change between wolves, sheep and plaque. Many lambs have already been eaten and those which remain are fleeter of foot and harder to catch. Wolf cubs cutting permanent teeth need more food and more gum massage to keep plaque at bay. In the competition for food a differential develops between the strong cubs and the weakest member. Harassed, affected by hunger and worsening periodontal disease the weakling is caught in a vicious cycle and dies. The remaining siblings benefit by the reduction in competition for food and the food (i.e. the sheep) benefit by reduction in wolf numbers.

Love thine enemy

The above example highlights the influence of periodontal disease. In the Diagram (opposite page) a number of organs are shown to depend on and to influence each other. If any one fails, a cascade effect engulfs the other organs within the cybernetic model. Take the heart as a starting point: as it fails it has an adverse effect on the bone marrow, musculoskeletal system, liver and kidneys. These systems themselves have multiple feedback effects:

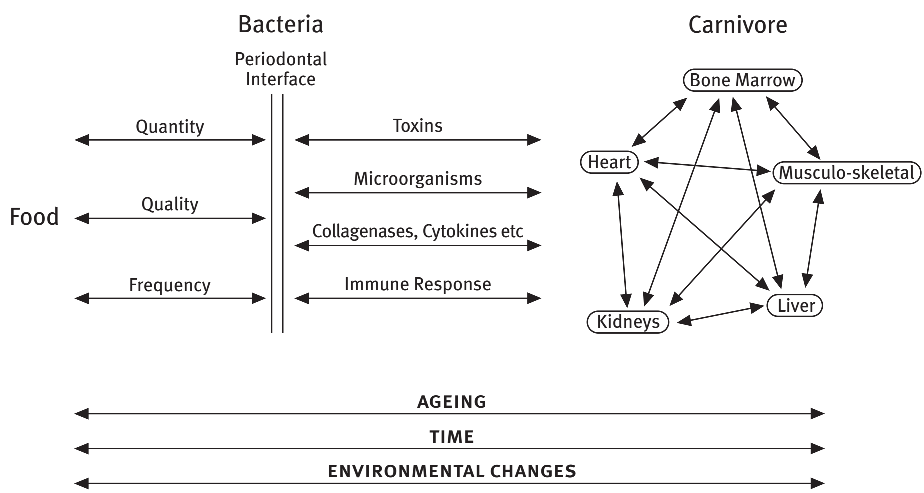
- A faulty bone marrow produces less red blood cells, thus requiring a greater output from the heart.
- A musculoskeletal system denied sufficient oxygen sends signals to the heart seeking a bigger output.
- The liver suffused with toxins and denied oxygen does not function at full capacity and thus fails to provide sufficient glucose energy to the cardiac muscle.
- Kidneys denied oxygen fail to clear toxins from the blood.
- Circulating toxins affect the heart.

Caught in a vicious cycle, the heart attempts to increase its output, resulting in further cardiac muscle damage.

Poor cardiac output means poor circulation in the gums with resulting build up of toxins and decrease in oxygen supply — a favourable environment for the growth of periodontal bacteria. Other changes in the internal environment of the subject animal contribute to immune changes. Whether hyperimmune, auto-immune, hypo-immune or any combination, each has an effect on periodontal organisms. The bacteria thereby come to 'know' information regarding the internal conditions of the host. We could say the immune system, by virtue of its actions, 'communicates' with the bacteria. The corollary here is that the bacteria 'communicate' with the immune system, which then feeds this information to the internal environment.

This view of the immune system acting as a two-way system of communication between the inner and outer environments is, I believe, an enhancement of the conventional view. In conventional terms the immune system uses 'soldiers' and 'clean-up crews' to maintain internal health of the individual. By according the immune

Linear Representation of Cybernetic Hypothesis of Periodontal Disease in Mammalian Carnivores



system a communication role, cybernetic control can be exerted between bacteria and individuals, individuals in social groups and social groups within ecosystems.

Communication is triggered at interfaces. A hand-tap to the head and a slap communicate different messages at the interface of hand and scalp. And both giver and receiver get the message. The sight and smell of roses communicate clear messages between lovers through specialised interfaces of eyes and nose. In modern science interactions and perturbations at interfaces are seen as key areas in the complexities of life.[7] For carnivores the key interface with their world is their teeth and gums — at once the source of their greatest strength and also their greatest weakness.

One other aspect of the immune system deserves mention. Under the conventional view the system protects the body. Adherents of this view are perplexed to find that frequently the immune system potentiates disease processes. To the cybernetician this is not a paradox, since depending on circumstances and the intersection of feedback loops, systems can have opposite functions. That the immune system serves both to protect the individual and ultimately to kill that individual is not inconsistent with the needs of either the individual, the community or the wider environment.

That the immune system serves both to protect the individual and ultimately to kill that individual is not inconsistent with the needs of either the individual, the community or the wider environment.

That is to say that, while life is important, death is no less important to the efficient functioning of natural systems. In our cybernetic model, life and death are two sides of the cycle. Death of a sheep ensured oral good health of our wolf pack with the resultant death of billions of periodontal organisms. The wolf pack of course lived as a result of the death of a sheep. The death of one sheep provided temporary benefit to the remainder of the flock which was able to return to grazing free from the wolves' attention — and incremental death by predation is better than mass death by starvation. When death did befall individual wolves, for the individual it was inevitable and better it was soon over. For the remainder of the pack less competition for food was a benefit. For plaque organisms in the mouths of wolves, sheep are the enemy. But more sheep leads to more wolves that must ultimately die. Plaque bacteria gain their best chance at life during the dying days of wolves.

Programmed cell death

> *Do not despise death, but be well content with it, since this too is one of those things which nature wills.*
>
> Marcus Aurelius Antoninus (AD 121–180)[8]

The Cybernetic Hypothesis refers to the incremental losses of herbivores and carnivores as a means of controlling their populations. Similar mechanisms appear to be at work elsewhere. Development of a mammalian embryo recapitulates the stages of evolution. At one stage the embryo has gill slits much like a fish, but the cells of the slits die to make way for the mammalian form. Similarly our embryonic fingers are joined together by a web. It is not that the cells of the fingers grow outward; it is in fact a case of the webbing cells being programmed to die at an appointed time.

Prior to 1972 no one suspected that the same programmed cell death is used to shape cell populations in mature animals. In that year a group of cancer researchers published a paper in which they introduced the term *apoptosis*, from the ancient Greek meaning falling of leaves, to describe the social control of cells designed to maintain balance within tissues.[9] At first there was little interest in the subject but now apoptosis is a frequently used word in science and medicine. There is even a Cell Death Society devoted to studying this phenomenon.[10] Speaking about the slow uptake of such ideas, Professor Barbara Osborne of the University of Massachusetts said: 'Sometimes it takes a while for something to sink in as being important. Everybody thought about death as something you didn't want to happen.'[11]

Now researchers have discovered that all cells have a genetically determined 'death pathway' and that under the influence of various chemicals apoptosis is either triggered or suppressed. A common example is that of the lactating breast. In pregnancy hormonal control produces enlarged breasts in readiness for milk production. Once the baby is weaned the milk-secreting cells, having served their purpose, commit suicide in response to hormonal signals. Other cells seem to have intrinsic biological clocks which govern their demise and which are modulated through a cascade of chemical signals. Pollutants, drugs and radiation exert some of their effects by apoptosis — as do the stress hormones, corticosteroids.

With our increasing awareness of the longitudinal and horizontal connections in the web of life we could expect evidence of programmed cell death in other areas. In the February 1995 edition of the journal *Science*, a paper was published describing mechanisms for the maintenance of healthy bacterial populations dependent on programmed death of some of their own kind.[12] Sometimes, however, apoptosis fails to occur as expected. Many cancers are thought to arise by constant proliferation of cells which should under ordinary circumstances die. But even suppression of apoptosis may confer benefits, being just another aspect of cybernetic control.

Now that scientists recognise programmed cell death and the regulatory role of death by predation and disease in populations, the question arises as to where periodontal disease fits in. It appears periodontal disease is the dependable disease of carnivores following on a failure to clean the oral cavity. Chemicals produced by plaque organisms trigger apoptosis of gingival cells.[13] If those same chemicals have a similar action on other cells, including cells of the immune system, this will suggest a possible mechanism of action of the Cybernetic Hypothesis.

Where do bacteria fit?

> *Nothing is too wonderful to be true, if it be consistent with the laws of nature.*
>
> Michael Faraday[14]

Sheep and wolves — which operate on our time scale and have physical dimensions similar to our own — are easy to conceptualise. Bacteria, though, being for the most part invisible, are easily forgotten. Such treatment of our ancestors is neither respectful nor prudent. Bacteria were here first — 3.5 billion-year-old rocks contain fossilised bacteria — and have always been the most numerous life forms.[15] Long before plants and multi-celled animals appeared the environment of planet Earth was regulated by and for the bacteria.

The Cybernetic Hypothesis, which concerns a subset of the vast range of the phenomena encompassed by Lovelock's Gaia Hypothesis, seeks to link the environment, herbivores, carnivores and plaque bacteria in an interdependent whole.

The Cybernetic Hypothesis, which concerns a subset of the vast range of the phenomena encompassed by Lovelock's Gaia Hypothesis, seeks to link the environment, herbivores, carnivores and plaque bacteria in an interdependent whole. And if we look closely, bacteria are active regulators at every level. Since Charles Darwin it has been known that life evolved from simple-celled organisms to the wonderfully diverse world of living things in existence today. Darwin commented:

> We cannot fathom the marvellous complexity of an organic being; but on the hypothesis [Darwin's theory of evolution] here advanced this complexity is much increased. Each living creature must be looked at as a microcosm — a little universe, formed of a host of self-propagating organisms, inconceivably minute and as numerous as the stars in heaven.[16]

Lynn Margulis, professor of biology at the University of Massachusetts, provides us with compelling evidence that bacteria living together, and then inside each other, gave rise to humans and the rest of multi-celled life. Rather than an arms race with competing species — as the poet Tennyson put it, 'Nature, red in tooth and claw' — Margulis describes a system of alliances.[17]

A prime example relates to how we came to breathe oxygen. Scientists suggest that when the first microbes emerged more than 3.5 billion years ago the Earth's atmosphere was predominantly carbon dioxide and water vapour. Those first inhabitants lived without oxygen gas (anaerobes) and it was another one billion years before the cyanobacteria appeared on the scene. These primitive forerunners of green plants — with the ability to photosynthesise sugars from carbon dioxide and water — produced oxygen gas as a by-product. Gradually the gas accumulated in the atmosphere until about 1.5 billion years ago, when the composition of the Earth's atmosphere stabilised at around 20 percent oxygen.[18]

Oxygen gas is toxic to anaerobes, which therefore developed ways of eluding the hazard. Some sheltered in mud or under other organisms away from the gas. Others evolved into aerobes which utilised oxygen for the release of energy from carbon compounds. When some oxygen-respiring bacteria took up residence inside anaerobes a blessed alliance was struck. A likely manner in which this occurred arises from the predator/prey interaction.[19] Early predators probably invaded prey cells in ways similar to the modern predatory bacteria. In most such encounters the prey died but in some instances the prey would have resisted to the point that, while weakened, it nonetheless survived. At first such mergers would have been shaky, but with refinement over time the union was perfected.

Both partners in the alliance needed to modify their old free-living ways in exchange for mutual benefits. The invaders gained food and shelter and the host cells the energy production and metabolites generated by the invaders' utilisation of oxygen — host cells were obligated to deliver oxygen to their fussy guests. It is fair to say that our lungs and circulatory systems are a direct response to that need to deliver atmospheric oxygen to the furthermost parts of a complex system of coevolved cells. Of course there were numerous links in the process commencing with coexisting bacteria and culminating in wolves, sheep and people — but it did take more than two billion years.

While the evolution of complex species inspires wonder, the fact that many bacteria have remained virtually unchanged since the early beginnings demands equal recognition. Anaerobes still require an oxygen-free environment, akin to that on the Earth at the time of the origin of life. And the biofilm lifestyle — complex alliances requiring 'check and counter-check' to maintain the balance — probably dates from the development of co-dependency between anaerobe species (aerobes came later).

While the evolution of complex species inspires wonder, the fact that many bacteria have remained virtually unchanged since the early beginnings demands equal recognition.

In the cybernetic model, bacterial communities maintain soil health for growth of herbage to feed sheep, sheep depend on rumen biofilms for the digestion of herbage, and wolves feed on sheep and are thus dependent on biofilms. But wolves as regulators also need regulating. It appears that plaque biofilms help close the ecological loop by hastening the demise of redundant wolves. Within plaque, anaerobes play a key role. They are essential for biofilm homeostasis and give rise to the odour and health effects of periodontal disease. In this age of mammals it appears that conditions on the planet may still be regulated by and for the anaerobes.

Corroborations and refutations

Before the Cybernetic Hypothesis can gain elevation to theory status new evidence will need to be brought to bear. There are three categories of enquiry, with much overlapping among them.

- First, there is the gathering of supporting evidence either from the scientific literature or from field observation — much existing information makes more sense when reinterpreted within a cybernetic framework.
- Second, the attempt to find counter-examples that refute the hypothesis; for instance a community of mammalian carnivores free from periodontal disease and living in balance with their prey. If the hypothesis survives the attempted refutation it is thereby strengthened.
- Third, perhaps the most significant category concerns the predictive and explanatory ability of the hypothesis. In this instance the hypothesis needs to predict and explain phenomena that are considered either unlikely or unexpected according to the current dominant paradigm.

The carnivores' susceptibility to periodontal disease differs from that of herbivores and omnivores. Within the context of the hypothesis this makes good sense. In the extreme a flock of sheep could all be at the brink of starvation when as a result of a rain storm their feeding fortunes recover. No particular advantage would accrue to a flock which suffered severe periodontal disease and reduced its numbers at the onset of a drought.

Paradoxically domestic flocks seem to be widely affected by early onset periodontal disease and resultant incisor tooth loss, regardless of the pasture. If the same occurs in the wild then this could be interpreted as a 'biological clock' mechanism designed to cull older sheep, thus making way for the young.

(Note: The term *periodontal disease* may act as an obstacle to our understanding of how the process intercalates with other influences affecting the biology of species and of the planet generally — other influences that we call *physiological* or *ecological*, and by implication are considered desirable, as opposed to a *disease* that by implication we consider to be harmful. However, in deference to common usage, I continue to refer to periodontal *disease*.)

Human omnivores appear to withstand a level of periodontal disease more readily than carnivores. In a cooperative species even periodontal disease affected individuals can be of benefit to the survivability of the group. But we do know that periodontal disease in modern humans tends to advance with age, which during our primitive evolutionary phase may have been an important regulator of the species.

Periodontal disease is mediated through the immune system which in turn is much affected by stress. As the authors of a paper entitled, 'Nutrition, stress and immune activation' explain in their opening lines:

> The response to stress (physical, social or microbial) provokes an integrated reaction involving the immune system (via cytokines), the central nervous system (via nervous output) and the endocrine system (via hormones) each influencing and influenced by the other physiological responses to environmental change. In this context, the concept of a link between nutrition and immunity is readily appreciated, in that nutritional deficiencies may cause stress or may alter central nervous system output and thereby impact on immune function.[20]

In expanding their argument, the authors propose the concept 'that changes in immune status have a feedback effect on nutrient intake'. If these authors are proved correct then this would lend support to the concept of animals and particularly carnivores entering a downward spiral of periodontal disease, starvation and death as their immune status declines.

The notion of a runaway decline in the health of hungry carnivores is the central theme of the Cybernetic Hypothesis. Multiple influences are thought to impact on the final outcome. It is both interesting to speculate and useful to know which metabolic pathways and feedback loops are responsible. In its August 1998 issue, *Nature* published information on this subject from a group of researchers at the Imperial College School of Medicine, London. In experiments on mice they found that a hormone, leptin, was a likely regulator of the immunosuppressive effects of acute starvation. Just 28 hours starvation triggered a fall in leptin levels which then precipitated a marked decline in immune function.[21]

Scientists observing the concomitant decline in nutritional status and immune function were surprised.[22] From the conventional viewpoint the immune system is supposed to protect the individual mouse and the conventional evolutionary perspective suggests that the mouse with the strongest immune system survives. But this narrow view seeks to confine the meaning of 'individual'. If we take 'individual' to signify a mouse family or mouse community or the entire species of mice, the emphasis changes. It may well serve the evolutionary interests of the individual wider communities if a single mouse dies. If we then widen our focus to the Gaia world of 'all for one and one for all' we can see that what we may initially perceive as individual weakness may indeed confer strength on the greater whole.[23]

Publishing the cybernetic hypothesis

Coming across a satisfactory explanation for some disparate and seemingly contradictory facts provides a great thrill for any scientist. Following the discovery you want to communicate the information to colleagues. Once published the ideas remain on the record for others to substantiate and accept or to refute and reject. There is a third possibility, and that entails the information being ignored and ultimately forgotten which is much the same as not being published at all. Within a few days of literally dreaming up the Cybernetic Hypothesis I had an article ready for publication. The few established facts used as supporting evidence were kept deliberately brief as a demonstration that the hypothesis was internally consistent and required little in the way of external support — besides, in 1992 I knew nothing of biofilms and apoptosis. In conclusion, I offered a challenge:

> The new-found hypothesis says that wild animals waiting to die suffer periodontal disease. Thanks to the efforts of the pet food industry the majority of pet animals receive calories but not physical cleansing of the oral cavity. These poor unfortunates

> are condemned to dwell in the antechamber of death suffering the ghastly consequences of a foul mouth and a variety of immune malfunctions. They are propped up by calorie intake, physical defence against predators and frequent visits to the vet. Alas for them they are denied the rapid and merciful demise of their wild counterparts.
>
> When the furore subsides this hypothesis should emerge strengthened and elevated to theory status. We can expect 'Road to Damascus' style conversions. The germ theory will be subsumed into a new paradigm with corresponding greater explanatory and predictive powers. The pet food industry will be compelled to withdraw its outrageous claims and may be required to compensate its victims. Veterinary teaching could gain a sympathy for its subject and be forever altered. The big question left to boggle the mind of the philosopher/scientist is: What next?[24]

There is an art to gaining publication and luck plays a big part too. Being inexperienced in the matter I decided to start with the *Australian Veterinary Journal* — the journal did invite submissions from ordinary members of the Australian Veterinary Association. I mailed the manuscript on 8 February 1993 and by 5 March I had a response. Both referees declared the paper was unsuitable for publication in the journal. One referee was moved to say:

> The article can also be construed as amounting to an unsubstantiated attack on the pet food industry and I wonder if this might not render the author and/or the *Aust. Vet. J.* liable to adverse criticism at the least if not some form of legal action or litigation.

This left me with the problem of where to direct my next publication attempt. Self-publication was an option, though I didn't seriously consider it. Thoughts of using the Internet did not, for me, exist at that time. And had someone made such a suggestion it would have sounded like science fiction fantasy — about as likely as getting the article published in the *Journal of Veterinary Dentistry*. But time changes things such that reversals are the norm. In March 1994 the *Journal of Veterinary Dentistry*, with minimal changes, accorded the article pride of place. Nowadays, it is also available on the Internet.[25]

What next?

What happens next is anybody's guess. Since carnivores occupy the extreme end of the food chain, some aspects of their biology are unique to them. But other aspects ought to have application further down the chain; for nature uses the same palette of colours at all locations. If the Cybernetic Hypothesis can explain how and why marginalised carnivores die, and if chewing on natural food proves to be the 'miracle prevention', then perhaps something similar applies to humans too?