Notes for a presentation on the 30th June 2009 in the main lecture theatre of the Linnaean Society, Burlington House, London on 'The Dynamic Relationship of Trees and Fungi: Symbiosis and Pathology',

(The significance of the venue is that this is where Charles Darwin presented his theory of evolution. Natural Inclusion provides an alternative theory).

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Here is the presentation from YouTube in 6 parts

1) http://www.youtube.com/watch?v=wORIPFa2sEk

2) http://www.youtube.com/watch?v=imE4iToMJLk

3) http://www.youtube.com/watch?v=vu3TlcMu2MU

4) http://www.youtube.com/watch?v=Db8OeyveFUY

5) http://www.youtube.com/watch?v=ldBw62OptUk

6) http://www.youtube.com/watch?v=QXiopcw88Vk

Preface added on the 27th September 2011

How great it would be for Natural Inclusion (NI) at last to get a receptive-reflective-responsive hearing in the 'desert of disregard', but I fear that that's simply not going to happen in anything like the near future, which is a source of considerable heartache and demotivation for me (and maybe the world!). A major source of blockage continues to be Holism. As I remarked to Ben Sidebottom, yesterday (and he agreed): Holists promote natural inclusional principles and values using anti-inclusional logic: upshot - living contradiction and tendency for insensitivity to individual sensitivity/needfulness/uniqueness. This is why I have come to feel that holists neither value nor recognise the distinctive contribution made to human understanding of NI (or myself), and carry on regardless of the sense it makes of their 'unity in diversity' paradox (cf for example, www.thrivable.org).

Summary

What does it really mean to be a healthy tree? And what is a diseased tree? And what do fungi have to do with these questions? And how might our answers depend on the environmental context in which we are considering them? This paper outlines the huge variety of ways in which trees and fungi enter into and influence one another's lives as dynamic embodiments of natural energy flow, and what this means for them both individually and collectively in the ecosystems they help to co-create.

Dangers of Definitive Categorization and How To Circumvent Them

It has become a deeply embedded habit of objective human thought to impose definition upon our selves and all that we observe as discrete subjects and objects. By so doing, we can seem to abstract order and clarity from the chaos of our environmental surroundings, and so establish a theoretical framework of rules and laws upon which to base our judgements and decisions. It can provide us with a reassuring sense of individual freedom and collective security in the knowledge that we can discriminate between one thing and another, good and bad, right and wrong – what is 'healthy' and what is 'diseased'. We have enshrined this sense of certainty in the logical foundations that underpin our conventional mathematical reduction of nature into fully quantifiable entities, that is, as discrete 'figures' isolable from their contextual 'ground'. But there is deep danger lurking when we are lulled into depending upon it as our way to progress to a desirable future, as is clear from Albert Einstein's comment that:

"As far as the laws of mathematics refer to reality, they are not certain, and as far as they are certain, they do not refer to reality"

What is a Tree?

"The tree which moves some to tears of joy is in the eyes of others only a green thing which stands in the way. Some see nature as all ridicule and deformity…and some scarce see nature at all. But by the eyes of a man of imagination, nature is imagination itself" -
William Blake

So it is that if we approach a tree as if it is little more than a solitary figure, a stake in the ground, set in a fixed reference frame by our objective eyesight, we may overlook its dynamic, living, context-dependent nature and consider its place in the world only as a potential resource, danger or obstacle to ourselves. Having no empathic feeling for how its past heritage and future potential are dynamically embodied in its present appearance as a manifestation of its habitat, any efforts that we make to manage its growth to suit our human desires may prove inadequate if not downright damaging to organism and environment alike.

If, on the other hand, we approach a tree seeking to understand it in ecological and evolutionary context from inside-out and from outside-in as a dynamic figure that both takes in and returns energy from and to its environmental ground, a more discerning relationship with its natural cycles of growth, death and decay may become possible. Instead of regarding the tree as an object, set in unnatural juxtaposition with and opposition to its natural neighbourhood, we understand it as a flow-form, like a river that simultaneously shapes and is shaped by the landscape it gathers and discharges from.

What is a Fungus?

"a sickly autumn shone upon the land. Wet and rotten leaves reeked and festered under the foul haze. The fields were spotted with monstrous fungi of a size and colour never matched before – scarlet and mauve and liver and black – it was as though the sick earth had burst into foul pustules. Mildew and lichen mottled the walls and with that filthy crop, death sprang from the watersoaked earth" – Sir Arthur Conan Doyle

As with trees, it is all too easy to allow objective vision to take a one-sided view of fungi, which alienates them from their natural neighbourhood. But for fungi this view can all too readily miscast them in the mould of execrable underclass, the destroyers and takers of life. Attention then focuses selectively on how to prevent or remove their appearance, instead of appreciating their significance as the natural world's great communicators and recyclers, whose role in life's endings is vital to life's openings.

If, on the other hand, we come to view fungi as relay channels for energy flow between underworld and outer-world, a much deeper understanding of their role in natural processes of growth, death and decomposition may be possible. Instead of estranging them as some class of lowlife that subsists at the expense or, at best, by courtesy of the trickle down economy of the grandiose, we understand them as riverine channels, veins and arteries delivering and returning lifeblood through the body to and from the hearts of natural ecosystems.

By perceiving the flow-forms of fungi in this way, as energetic configurations of figure in ground and ground in figure that connect within, to and from those energetic configurations of figure in ground and ground in figure that comprise the flow-forms of trees, we may be better placed to question their role in the health and disease of those they include within their natural neighbourhood.

A Question of Health and Disease: How Do Trees and Fungi Relate?

From the foregoing, it is clear that we can address and hence answer this question in different ways. The answer that predominates, to this day, under the influence of positivist science and Darwinian evolutionary theory is 'as self-centred objects'. This is the answer that comes from our *rationalistic* predilection to impose definitive limits between subjects and objects as independent figures of 'one thing or another', regardless of the common ground of receptive space that both include and are included by as dynamic flow-forms. It is the answer that comes from dividing nature between 'one' as a 'whole' and 'many' as 'parts', and so sees life as a competition or 'power struggle' for 'superiority' over 'others'. But deep in the heart of this division lies profound inconsistency and paradox, rooted most fundamentally in the groundless supposition that material 'form' can be isolated from the immaterial 'space' that gives it size and shape. With this supposition comes an attitude of mind predisposed to conflict by making an enemy of 'other', out of the context of the limitless openness that pools all dynamically together as flow-form. And so it can be that fungi become represented either as 'foes', *against trees*, or as 'friends', *with trees* in their relentless struggle for life regardless of circumstances. At best, this representation is simplistic – the product of a crude mental removal of what is vital to life, which sacrifices 'truth' for the sake of 'convenience'. At worst it leads to abusive mismanagement and damage.

The answer seldom heard – as yet – comes from what has been called the *inclusional* understanding of natural energy flow as the dynamic inclusion of infinite receptive space in local form and local form in infinite space. According to this understanding, trees and fungi relate as natural neighbourhoods, with each as a dynamic inclusion of the other's influence. This understanding transforms the competitive representation of evolutionary processes on the basis of selective advantage, into a *co-creative* flow of all through all in receptive spatial context – what has been called *natural inclusion*.

The Rationalistic Approach: Cost-Benefit Analysis

The conventional rationalistic approach to categorizing relationships between different kinds of organisms is in terms of economic transactions between two parties, which result in gain (represented below as '+') or loss ('-') – or neither gain nor loss ('0') – to one or both. Correspondingly, it has become widespread practice, as described in many biological and ecological textbooks, to categorize these relationships into six basic types along the lines of the following schema:

\+ + Mutualistic

\+ - Exploitative - parasitic, predaceous, herbivorous

0 0 Neutral

\+ 0 Commensal

\- 0 Amensal

\- - Competitive

Within the context of this schema the term, 'symbiosis' may be used narrowly only to refer to mutualistic partnerships between organisms, or more widely, in accord with Anton de Bary's original intention in introducing the term, to refer to any persistent 'living together', regardless of outcome. What is meant by 'cost' and 'benefit' may also vary with what is perceived to be the interactive mechanism underlying the relationship. Very often this is

nutritional, especially in the case of fungi and plants, where the former are 'heterotrophic' and hence ultimately dependent on other organisms for their supply of organic carbon, whilst the latter are (usually) autotrophic (i.e. photosynthetic) and requiring only mineral nutrients and water to sustain their growth. So, for example in the 'fungus-roots' of mycorrhiza-forming plants, mutualistic partnership is generally considered to result from the supply of organic compounds by the plant to the fungus, whilst the plant receives mineral nutrients and water from soil via the fungal mycelium.

There is an obvious linkage between this view of inter-organism relationships and our human notion of trade between two discrete individuals, which is reinforced by some of the associated terminology of 'costs', 'benefits' and 'trade-offs' that has become widespread in evolutionary ecology. But this raises the question of whether the categories identified are truly 'natural', or the result of an anthropocentric projection of human rationalization onto nature for which we selectively gather 'evidence' that fits our expectations as self-fulfilling prophecies.

Problems with the Rationalistic Approach

Despite and because of the apparent simplicity and ease of communication of the above schema, it may obscure rather than enhance our understanding of organism-environmental relationships, leading to profound inconsistency and complication through its circumvention of the inconvenient reality of natural energy flow. The key problem, from which all others follow, is its foundation in the premise that organisms can be regarded as fully separate material objects, dislocated from the common space of their environmental ground. Correspondingly:-

1. It is difficult to evaluate 'cost' and 'benefit' impartially. How can these realistically be measured? What criteria are being used to make such measurements? Are such criteria, for example nutritional exchange rates, independent from other criteria such as protective, environmental, developmental and reproductive influences? What truly constitutes a 'loss' or a 'gain' within the context of natural energy cycling, redistribution and evolutionary ecological transformation? Should our attention focus on 'individuals' or the 'populations' and 'communities' of which they are members?

2. Why restrict attention to one-to-one transactions – why not include the influence of and upon others, including the environmental context of the habitat or ecosystem within which these transactions are supposedly taking place? Actually, the answer to this question is only pragmatically rather than intellectually justifiable. It lies in what is known as the 'three-body problem', whereby, as Isaac Newton himself came to recognise, the outcome of three or more bodies interacting under one another's simultaneous mutual influence is impossible to calculate with certainty using conventional, discontinuous mathematical formulations. But then, what truly natural situation *doesn't* involve three or more identities simultaneously influencing one another?

3. What are the implications of restricting attention to a fixed reference frame (as is necessary to avoid the three-body problem using discontinuous mathematics) and so holding spatial context impossibly static? In effect, what is done here in order to try to simplify the dynamics into a manageable 'small picture' introduces non-existent structural limits that constrain and complicate the natural situation.

4. By excluding or confining the infinite (i.e. indefinable, indivisible) openness of space from or within rigidly closed structure an unrealistically *prescriptive* model of evolutionary process is generated, which does not allow for natural variation. What appears to be gained by way of calculable predictability may lessen awareness of natural sources of uncertainty, making us ill-equipped to respond sensibly, sensitively and creatively to unforeseen possibilities.

The Inclusional Approach: Flow and Counter-flow

"In nature everything is distinct, yet nothing defined into absolute, independent singleness" – William Wordsworth

The inclusional approach to understanding organism-environmental neighbourhood seeks to recognise and account for distinctive possibilities without defining them into hard and fast categories or separating organisms out of context as discrete objects. Instead of imposing unnatural boundaries as definitive limits to the *fixed frameworks* of objective terms of reference, it works with natural, variably fluid boundaries as the *dynamic framing* for its open-ended focus on co-creative evolutionary processes of energy flow. Correspondingly:-

1. It involves truly *impartial* evaluation of natural energy flows coming from *all angles* and not biased to one side and/or another. Individuals, populations and communities are all included as distinct but not discrete identities flowing into and out from one another.

2. It is fully *contextual*, inclusive of the ecological neighbourhood that inter-organism relationships form in and transform. It takes into account, instead of seeking to ignore the 'three-body problem'.

3. It is dynamic, accounting for continually changing circumstances in limitless space. The macrocosm dynamically includes and flows into the microcosm as the microcosm dynamically includes and flows out to the macrocosm, without finite end or beginning.

4. It is evolutionarily inclusive of receptive space as a vital presence, and so is realistically non-prescriptive and open to possibility. Evolutionary 'learning' generates complexity and variety through *improvisational* processes that incorporate past heritage and future possibility into present expression. The true *craft* of the practitioner who works with these processes is similarly improvisational and context-dependent, not rigidly prescriptive.

Agents and Agencies: Origins of Health and Disease

"...the microbe is nothing, the terrain is all" – Louis Pasteur

Rationalistic and inclusional views produce very different understandings of *causation*, albeit that the former can be transformed into the latter through the inclusion of receptive space – as Louis Pasteur's death-bed renunciation of 'germ theory' may testify. They may hence yield very different understandings of the role of fungi in the life and death, health and disease of trees.

From a rationalistic perspective, any 'effect' or 'reaction' arises from the 'local causal action' of a forceful material 'agency'. On this basis, many kinds of fungi are often described as 'pathogens', i.e. as 'causes' of disease in trees. By the same token, some fungi, notably mycorrhizal fungi and decomposer fungi that facilitate nutrient cycling and inhibition of pathogenic activity in soil may be afforded the status of 'health providers'. Moreover, since

these fungi are regarded individually to be ‘self-contained’ closed systems, their actions are readily interpreted *as if* they are directed by some internal ‘will’ or ‘genetic code’ that seeks to perpetuate itself at all cost. Such interpretations fall readily into line with the ‘self-assertive’ principles of neo-Darwinism that have become so deeply embedded in modern human culture, based on the quest for dominion over Nature in the ‘struggle for life’ that results in the supposed ‘survival of the fittest’.

From an inclusional perspective, however, no form or movement is possible without a receptive space for its accommodation, and this space is not confined solely to ‘somewhere local’, but extends continuously to everywhere, without limit (i.e. ‘non-local’). It is this receptive ‘host space’, not forceful local agency, which is the omnipresent ‘unmoved mover’ of nature that *induces the flow of form into place* in a potentially infinite variety of dynamic configurations.

Correspondingly, it is the inviting host space within a tree that could be said to draw fungal flow-form in to make itself at home, sustained by the flow of energy sources delivered via photosynthesis. What the implications of this induction may be will depend on how the fungal flow fits in with current circumstances of the tree as a figure in the terrain that it grows into as water, sunlight and minerals feed from the terrain into the figure.

Rationalistic and Inclusional Perceptions of Health and Disease

In the contrast between the rationalistic and anthropocentric perception of the differential ‘survival of the fittest’, and natural inclusion as the differential ‘sustainability of the fitting’, comes a radical difference in understanding what it means to be ‘healthy’ or ‘diseased’. The former view equates ‘health’ and ‘fitness’ with productivity, and lack of productivity with being ‘unfit’ or ‘diseased’. The latter view associates attunement with the energy flows of natural neighbourhood with ‘healthiness’ and ‘fitting in’, and discordance with these flows as ‘miss-fitting’ and ‘dis-ease’. The third part of this paper will explore examples of the dynamic relationship between trees and fungi from this inclusional view.

Trees as Host Space For Fungi: Embodied Water Flows From Roots to Branch and Back

"A tree is a solar powered fountain, its sprays supplied through wood-lined conduits and sealed in by bark until their final outburst in leaves…Within and upon its branching, enfolding, water-containing surfaces, and reaching out from there into air and soil are branching, enfolding, water-containing surfaces of finer scale, the mycelial networks of fungi…which provide a communications interface for energy transfer from neighbour to neighbour, from living to dead, and from dead to living" – Alan Rayner, Presidential Address, British Mycological Society, December 1998

Water Pipes and Gas Pipes

As we try to understand how fungi make themselves at home in the host space of trees, we need to bear the following points in mind:-

- Growth and metabolic activity in fungi is dependent upon aeration. Although some fungi, like yeast, can ferment sugar to alcohol in the absence of oxygen, their growth and metabolism is much enhanced by aerobic respiration. Breakdown of lignin, for example, is a highly oxidative process.

- Oxygen and carbon dioxide diffuse around 10,000 times faster through gas than through liquid water.

- The distribution of moisture and aeration channels in trees varies and correspondingly both influences and is influenced by the distribution and activity of fungi

- This sets the scene for complex, dynamic relationship between the function and dysfunction of trees as solar-powered fountains and the fungi that inhabit their interiors and exteriors. This relationship is very sensitive to changeable environmental circumstances.

What Influences Moisture and Aeration Distribution in Trees?

The following factors are important:-

- Wood and bark anatomy. Bark is the insulator between a tree's exterior and conductive channels in wood. The latter are predominantly oriented axially, along the length of the tree's trunk(s), roots and branches, as well as radially, through the medullary rays.

- Seasonality. Sap flow varies at different times of year, commonly being under pressure and in relatively large diameter channels at the beginning of the growth season and under tension, in smaller channels at other times.

- Activity of inhabitant organisms. Growth and metabolism of inhabitant organisms may result in loss of conductive function, expansion of aeration paths and alteration of gaseous composition within trees.

- Loss of conductive function: cavitation, increase in girth and heartwood formation. The formation of gas bubbles in water columns leads them to break or 'cavitate' and hence to a loss of conductive function. This tends to increase with age of wood, so that only the outermost sapwood is fully conductive. Heartwood, rich in extractive phenolic and terpenoid compounds derived from acetate and shikimate secondary metabolic pathways may form as the wood becomes dysfunctional and gas-filled.

- Relation between supply and demand – root to shoot ratio. Prolific branching systems or shoots may place high demands on what can be supplied from existing roots, resulting in loss of function in some.

- Death and removal of bark and living tissue due to damage and disease. Removal of a tree's insulation will expose the underlying conductive channels to ingress of air, especially when water columns are under tension.

- Physiological stress, especially drought. Any kind of external stress can inhibit physiological functioning and water conduction, especially water stress.

- Hydrophilic and hydrophobic compounds. Production of hydrophobic (water-repellent) compounds like suberin, phenolics and terpenoids can serve to seal off dysfunctional from intact, water-conducting tissues. These compounds can also inhibit fungal growth directly.

Fungal Home Life

It follows from what has been said so far that:-

- Fungi are most active where their aeration and moisture supply are adequate but not excessive – neither too wet nor too dry – and inhibitory chemical compounds are minimal. These conditions tend to be met in non-living tissues that have lost function.

- Fungi can be present in latent or dormant form even when active growth is restricted. Even where anoxic and chemically inhibitory regimes are present, fungi may be capable of surviving or developing in cryptic form as 'endophytes', which become active when the inhibitory conditions are alleviated.

- Fungi can themselves enhance the receptivity for their accommodation in tree space. For example, by inducing dysfunction in water-conducting tissues through killing living cells in vascular cambium and elsewhere, fungal activity can induce the spread of aeration channels.

- Close encounters of the fungal kind can be many and varied. It is common, especially where inhibitory conditions are alleviated, for more than one kind of fungus to colonize the same tree or location within a tree. These fungi may influence one another and their contextual circumstances in a wide range of ways.

Homing In and Around Roots: Rotters, Communicators and Friends of the Earth

Like rivers flowing within the basins outlined by their watersheds, the influence of roots does not stop at their physical surface, but reaches far out into the surrounding soil. Here a wide variety of fungi, as well as other micro-organisms, may be induced into activity within what is called the 'rhizosphere'. Some of these may make their way to the root surface or 'rhizoplane', and from there into the root interior. Many of these can form what are known as 'mycorrhizas' or 'fungus-roots', acting as absorptive accessories that can greatly extend the surface area through which water and minerals can be taken up from soil. The presence of these fungi can strongly enhance tree growth, especially on nutrient-limited soils, a fact that has led them to be regarded widely as mutualistic partners. But they can also make strong demands on host photosynthesis – estimated in some cases to be as much as a quarter of annual productivity – and can also support the growth of parasitic plants like *Monotropa* that indirectly feed through them. So the question of how much they truly benefit trees may be a moot point and very context-dependent. Moreover, their influence is not confined to nutrient

flow. They can also affect the aeration conditions in soil around roots through their production of hydrophobic and hydrophilic mycelium, they can filter out the take up of toxic metal ions from soil, they can induce developmental changes in root growth and form, and they may impede the entry of 'pathogenic' fungi. Unlike mycorrhizal fungi, the latter induce dysfunction in the root tissues, often by way of an advancing coating of mycelium that secretes enzymes and metabolites that kill living cells – familiar examples being species of 'honey fungus' (*Armillaria* spp.) and *Heterobasidion annosum*.

Underground Connections – Sources of 'Fellowship' and 'Parental Care'

It has only been appreciated relatively recently that the mycelium of mycorrhizal fungi that links roots to soil can also form communication channels between roots of one plant and another plant, bringing scope for flow between them. Depending on the relative specificity of association between fungus and plant, the resulting connections can join plants of the same species or different species, and younger plants with older plants in a common underground network that sustains each in communion with the other as sources and sinks. So, what appear to be separate entities above ground are joined together below ground, in much the same way that what appear to be 'islands' above sea level may only be the peaks of a submerged mountain range.

A Cavity at Heart

As roots join in to the butt of mature trees, from which one or more trunks emerge, so a new possibility for fungal home-making arises in the relative seclusion of the dysfunctional core of heartwood. Here those relatively few kinds of fungi attuned to the carbon dioxide-rich gaseous regime and presence of inhibitory extractives can grow slowly but surely for decades, eventually coming to inhabit volumes of wood measurable in cubic metres. As they do so, they break down the woody cell walls, hollowing out the trunk and redistributing its carbon content into the outgrowth of what can be huge fruit bodies or gatherings of fruit bodies. Whilst this process might be regarded as a source of loss from the tree, it occurs in non-living wood and need not greatly diminish the strength of the trunk as a hollow cylinder. Moreover, the decaying remains provide a habitat for a variety of fauna and become invaded by the tree's own roots and mycorrhizas as it mulches down into humus.

Out on a Limb

A tree that retained all the branches it ever produced during its life would soon become a dense thicket. In reality the vast majority of branches die back and are shed sooner or later by a process of 'natural pruning', which enables the airy canopies of mature trees and their main thoroughfares to form. These branches decrease in number and increase in diameter as their 'order' increases from 'low' to 'high' from the outermost fringes towards the main trunk or trunks. Low order branches become dysfunctional – perhaps primarily due to limitations of water supply relative to their demand – more readily than high order branches, but on most mature trees at least a few moribund large diameter branches are usually present, and in genera such as *Quercus* (oak), with a durable heartwood, they may remain attached for many years even after the sapwood has rotted away.

Branches undergoing natural pruning often support a characteristic assemblage of decay fungi. For example, oak branches of progressively higher order support *Colpoma quercinum*, *Peniophora quercina*, *Vuilleminia comedens*, *Stereum gausapatum* and *Phellinus ferreus*. Many of these fungi may initially become established in fully functional sapwood as endophytes, which only become fully active as this becomes dysfunctional and aerated – in which case the relative contribution of the fungus to the dysfunction is debatable.

Endophytic fungi may also become active in the trunks and branches of trees subject to physiological stress, notable examples being *Cryptostroma corticale* and *Dichomera saubinetii* in sycamore, *Biscogniauxia nummularia* and *Eutypa spinosa* in beech, *Daldinia concentrica* in ash, and *Hypoxylon fuscum* and *Stereum rugosum* in hazel. Their distribution patterns differ markedly from those of fungi that grow into the sapwood of trunks and branches from wounds – these latter closely follow the spread of aeration in the dysfunctional wood, and are inhibited from spreading further by the production of hydrophobic sealant zones.

Encounters in the Fallen World

As wood and foliage is cut or shed from trees, it becomes host to an increasing diversity of fungi that contribute to its decomposition, returning its organic and mineral content

eventually to the humus content of soil. The mycelia of these fungi show very obvious territoriality in their encounters with one another, sometimes mutually blocking one another's expansion, sometimes encroaching into and replacing residents. Moreover, in some species these mycelia can integrate into cable-like mycelial cords that forage out into soil to link up local feeding sites in patterns that show extraordinary versatility and economy of effort. As they return the tree's remains to soil, so the mycelia of mycorrhizal fungi may take up the flow and return it through the tree's roots.

Opening Ending

From the perspective of natural inclusion, death does not end life, it feeds and opens the possibility of renewed life. Life is not a competition to succeed at others' cost, it is a gift of natural energy flow, to be accepted and passed on in continual relay. Trees and fungi are no exceptions from this flow. Perhaps we need to bear this in mind as we seek to distinguish between what is healthy and diseased, and cultivate the terrain in which all flows through all.