The Two Sciences

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I suggest that there are at least two sciences, two almost opposite ways of doing science and applying it for human benefit. The first is the one most of us think of as science - a highly sophisticated understanding of nature, which has led to so many applications. This science, in spite of all its obvious successes, is also in bad repute among may people. The atom bomb was a major example of mis applying the power atomic science gave us over nature. The recent disease problems like BSE accentuated public mistrust.
The other science comes from more immediate observation and especially admiration of nature. This is the science behind organic farming, behind various food fads, complementary medicine - all areas that have become examples of what most people would call anti-science. My point is that actually there are aspects of the latter that is not only good science, but likely to become a better and more profound study of nature , at least for biology and ecology.

Looking back, I think I have always lived with this idea. Growing up in what was then a rural area in Buckinghamshire, I was aware, 'helping' on the farm at the end of our garden, that there existed that science that understood what the farmer was doing and advised him about improvements, and quite another potential science that told us how little was in fact understood, and how applications of science should encompass these more extensive aspects of what was actually happening on the farm. Soon I was growing veg in our garden as much as we could with compost and composted manure. As a student in biochemistry I used the facilities in our bacteriology classes, to try to culture whatever would grow in 'QR compost maker. This was and still is, a powder made from oak bark, honey, etc according to a formula invented by a lady (Miss May Bruce) by instinct, with little or no scientific training. But my nutrient culture dish was covered in less that 24 hours with all manner of micro organisms, notable among them the tutor pointed out, were slime molds. Here was clearly some farming science to be done, which had been neglected. The same notion entered in other contexts in the biochemistry classes. For instance, that well defined enzymes, like the trypsin in our stomachs, is well established as the catalyst that digests proteins, or more specifically splits the bonds between just two pairs of amino acids. So we call it a proteolytic enzyme. But then it was found that it also splits the bonds of any organic ester, the combination between an alcohol and an acid. Here it has almost no specificity for particular esters.. so there are other things going on than appear at first. that of course is what you expect in any advancing science. Questions arise when one applies any of the science - if you only know some of the story, is it wise to apply what you do know?

Notes: see Homage to Gaia. example of looking at a whole scene and then searching for the detail. Most conventioanl science starts with a defined detail. Thus in a way the process is reversed. Convenital scineitsts cannot usually accept the generalsiation first - it must come afterwards as a conclusion.

voice notes: nature can afford the luxury of having humans only to a limited extent. now that an established science has been created, we can afford to look in the other direction in a more holistic manner. The scientific attitude distinguished what is real from what are our beliefs and myths. The power of scinece has now become so great that it has political, economic, religious and philosopphical implications that cover all of our lives.
the scientific attidtude distinguishes what is real from beliefs and myths. It questions and challenges basic assumptions continuously. It has now become so powerful that it affects politics, economics, philosophy and religion and many other aspects of life. Science, the scientific attitude distinguishes what is real from beliefs and myths that are unsubstantiated. It constantly questions and challenges basic assumptions . It has now become so powerful that it affects politial, economics, philosophy religions and many other aspects of life. And conversely, these determine our scientifi priorities and education in science.
SCIENCE is seen by many people as a huge advancing attitude tat has progressed and shaped our world. So it is and so it has. Science over the past 500 years provided the understaniding of nature that gave Europe the chance to conquer, harness, nature and most of the countries of the world. The result is both the high quality of life created ofr many, the great expansion of the human population and much longer life expectancies. The result is also that for the first time ever in the evolutio of the planet, a single species has

achived suc domiance. Of course it is not just the understanding of nature, which the ancient Greeks and the Arab nations of the middle ages also shared, but the applicatin of that knowledge to technological advance. That was the innovation that marked the rise of European civilisation from the Rennaissance. All this has been written about an debated so much, the only purpose in recalling it here is to set the scene for this essay.

IN passing though, one must also recall tat there have been some other large technological civilisations. Large

Start here:
Unashamedly I plagiarise C P Snow's idea, both for my title and to describe a division in society that becomes all the more apparent, the more one generalises and simplifies. In this essay I show that the apparent polarisation between the "hard sciences" and popular antagonism to science is based on two very different perceptions of what science is about. The polarisation has become intense in the last years, especially in the areas of biology, agriculture and medicine. I am proposing that there is another science, one that gets to the roots of its philosophy, is as rigorous as existing science, and one that would be more enthusiastically welcomed by a wide public. I call it Natural Philosophy; unashamedly again taking this term from the origins of modern science, a term we all use for the degree Ph.D or D.Phil.

"The scientific process has two motives: one is to understand the natural world, the other is to control it." (Snow 1964). I make the case that the desire to control has deep evolutionary and cultural roots. This control however has become split into two very different approaches; the one to conquer or overcome nature; the other to harness natural processes but not overcome them. That divide now splits society and is at the root of the antagonism against science and the apparent lack of appreciation of science, (that Snow tackled). Natural Philosophy would re-combine that split, and would be a science that is more readily communicated. It might even help to overcome the split between C P Snow's Two Cultures.

To start the discussion, I have chosen the example of agriculture. Farming has changed more of the world and for longer than any other human activity – successfully feeding a now huge population but at the same time causing endless ecological damage. Agriculture is now a dominant applied science, (in the sense that it covers a large part of the world's land surface) and has been a vital technology for humanity for thousands of years. The advances achieved during the $19^{th-20th}$ centuries seem to contradict Malthus's assumption that food production can only increase at a linear rate, while population increases exponentially.

Since Malthus, the development of fertilisers during the nineteenth century revolutionized farming. Liebig in the 1830'-40's discovered that plants can flourish when given only soluble salts containing N, P, and K nutrients. Rothamstead experimental farm was founded in 1843 as a direct results of Liebig's work and the trials started then are still continuing. The farming methods that grew out of this discovery have succeeded in feeding the world for more than 150 years. Rothamstead has become one of the great agricultural research centres of the world. Research on plant nutrients and improved formulations of fertilizers has continued actively for over the past century and especially the last 50 years, adding numerous minor nutrients, the micro-elements. Now 40% of humanity depends on the Haber-Bosch synthesis of ammonia (developed initially for explosives in WW1) from atmospheric nitrogen. (Smil,) Nearly half of your body's protein is made from this fixed nitrogen via ammonium and nitrate fertilizers. This is a scientific success story. Being such a success, its own momentum further stimulated the approach, in cycles of positive feedback. The approach continued with the corresponding development of mechanization and of powerful pesticides (partly products of WW2) that further increased yields and profitability far beyond what was dreamed possible in the 1850's. However this approach has also led to the ecological problems that arise from greatly intensified agriculture. Nitrogen fertilizers alone are a cause of widespread pollution and they increase the susceptibility of crop plants to diseases, requiring yet more pesticides.

A different scientific advance developed alongside this success story. This is the science of how plants actually *do* take up their required nutrients in natural conditions, in contrast to how they *can* do so given the opportunity. In most situations in nature, nutrients are largely bound in soil particles and organic matter. Plants absorb these nutrients in symbiosis with soil micro-organisms. Mycorrhizal fungi were recognised nearly 40 years after Leibig's work (by Franciszek Kamienski in 1882 in Russia) but it took many years to realise that this fungal symbiosis with plants benefited the latter by releasing bound nutrients directly into plant roots. This is so basic to plant growth that it is now thought probable that plants were originally only able colonise land by symbiosis with micro-organisms. It should therefore not be surprising that the evolution of inter-dependant ecosystems would result in some close connections between soil biota and plant health. After many decades of relative neglect, the study of mycorrhiza and their significance in the ecology of the soil is again increasing. The mycorrhizal hyphae effectively double the extent of a plant's roots; both research and marketing of fungal preparations is being promoted.

However, this mechanism of plant nutrition was, and still is, largely ignored in the practice of conventional farming. For example, the Conference held to celebrate 150 years of research at Rothampstead contained no mention of mycorrhiza in its report (Leigh et al, 1994).

Here then are two very different ways of applying biological understanding to farming, each separately based on rigorous scientific findings. In the first, the crops are supplied with their needs by addition of fertilizers; in the second, the nutrients are delivered through rotting organic remains. While there is no rigid dividing line between these two approaches, they are in fact to a large extent incompatible. You cannot do both at once.

There are two main reasons for this incompatibility, one of attitude and one of biology:
a) the attitude about what constitutes good science. The conventional agricultural science rests on proven successes which are simple, direct, quickly realized, easily repeatable and easily proven. Its very simplicity is one of its strengths: a short-circuiting through the complexities of nature which are thereby avoided and of little further concern. The method works and represents another natural constraint to growth that has been successfully overcome. The second science can similarly demonstrate successes but these are less easily proven; this science deals with complexity and is not simple, the processes are mostly indirect, most remains unknown, the results are only slowly realized and because of the complexity, they cannot be so readily tested. Rather than short-circuiting natural constraints, this approach overcomes them by modifying natural processes to suit humans better. The simplicity of the first approach depends on omitting from consideration the complexity of the second. This latter complexity remains nevertheless a scientific fact. It is a matter for judgment whether omitting it is unwise or useful. That judgment distinguishes these two attitudes.

b) secondly, the two approaches are technically incompatible because soluble nutrients inhibit the growth of mycorrhiza. As a result, the conventional farm becomes rather deficient in soil fungi, so the nutrition of the plants has to depend on those applied fertilizers. Measurements of soil nutrients on some organic farms have shown how deficient soils can nevertheless yield rich crops – those tightly bound nutrients did not show up in chemical tests, but they were there and bound and could be taken up by mycorrhiza. Of course organic wastes can be, and are, applied to fields that are routinely supplied with fertilizers, but this does not usually allow either extensive accumulation of humus or development of the soil micro-flora.

If we accept that these two simplified stories show how the scientific description of plant nutrition can progress in very different ways, we may be justified in suggesting that there exist two very different sciences, each in their different ways and each rigorously scientific. To distinguish them, I will for the moment call the first approach "conventional science" and the second "natural philosophy".

To describe this difference more fully, I will use a number of further examples. I also need to clarify how there is room in society for different sciences, and indeed in coining the word "Two" in my title I fall into the same trap as SC Snow: there is of course a multitude of cultures and a multitude of sciences. The word "two" is a gross simplification to make it easier to describe the differences.

[Most conventional scientists would argue that the "natural philosophy" approach is full of unknowns, cannot be tested or proven, and is guided by ideology rather than science. The latter "natural philosophy" scientists would argue that the conventional omits many features of the biology of plant growth which are essential parts of the story. Both arguments are valid critiques.]

One might say that this science just adds to understanding as a whole. But as described below, these two approaches are incompatible. The science stands on its own, by itself; there is nothing in the science that helps one to think about its meanings and how to decide which direction to follow. Scientific argument can help but little in the choice between them, to decide which one to follow in the development of agriculture. The choice will depend as much on ones attitude as on the technical consideration. I expand here on why this is so.

(We are here concerned only with how plants absorb their mineral nutrients; one should note in passing however, that these ideas about the health of plants seem to extend to animal health as was eloquently documented by Sir Albert Howard (1940); his cattle resisted foot-and-mouth disease even when in contact with diseased animals. His friend McCarrison extended the idea to human health.)

The problems as well as the successes are both the results of short-circuiting natural processes. The costs appear as unwanted "side effects" which must be dealt with.
one which avoids short-circuiting natural processes.

If we accept that both approaches are indeed scientifically sound but in the different ways described, then it follows that scientific argument alone cannot choose between them. The choice depends on the scientist's attitude, which cannot be based purely on the rationality of the argument, because both are equally rational. Therefore the choice becomes necessarily based on ideology of some kind or other. It becomes an intuitive hunch based on past experience, which will be the main influence on the choice. A crucial choice of this sort was made in 1946-7, in the House of Lords, leading to the 1947 Agriculture Bill.

1. there really are two ways of doing science
2. depends on what you are satisfied with
3. cannot successfully teach or preach the conventional in the face of the new
4. on the whole, they are philosophically and practically incompatible
5. yet both follow long-standing traditions:
6.

A second closely similar example has also been neglected. There is good evidence that plants achieve their own "integrated pest management" (IPM) by maintaining low concentrations of amino acids in their cell sap, with high through-puts so that protein synthesis continues. Pests and diseases starve without sufficient free amino acids. If nitrate is over-supplied, or protein synthesis interrupted with pesticides or herbicides, the levels of amino acids rise, feed the pests and the IPM fails with increased susceptibility of plants to diseases and pests, (Chaboussou, 1985, 2004). "Biological control" of plant pests has become all the rage, yet the science of this does not recognize Chaboussou's or similar work; for example, a Royal Society Symposium on biological control of pest held in 1987, did not mention the possibility that the health and nutritional of physiological states of the plant were the most powerful control of susceptibility.

These two cases make one question why the neglected biology has not been further explored. I suggest two reasons: one is that the conventional approach yielded immediate results of the kind that was needed. Fertilisers lead to higher yields immediately, and pests are killed immediately with pesticides. In contrast, the more thorough biological science has not been developed, because these applications would take time. A more ecologically based husbandry would after maybe some years, give high yields of healthy plants, solving both problems of fertilization and freedom from pests. But such results are not immediate. The basic instinct to apply what works now and overcome natural constraints takes precedent, fits with the age-old attitude of conquering nature. The second reason is that the conventional methods of husbandry actually inhibit the alternative natural processes: fertilizers inhibit mycorrhiza, so their presence is not so noticed and is not researched. Similarly, fertilizers and pesticides encourage pests by inhibiting the plant's own defences, so these become less apparent. So for these biological reasons, research and development is neglected.

Thus we have a situation in which, once started, the conventional wisdom becomes self-promoting. There are many other examples, which are discussed below.

Some might notice that the above examples reflect the opposing approaches between conventional and organic farming. They do but there is much more to the differences between them, and they are based on the evolution of scientific thinking. Conventional science has its origins essentially in physics, later creating and expanding the science of chemistry. Biology came in first as "natural history", which was/is the description of all the features of nature and wilderness. It is only relatively recently that biology has evolved into what we might call an "exact" or a "hard" science. It is mainly in the scientific applications to life that my proposal of a new 'natural philosophy' is important.

Notes:

Note that the natural philosophy approach is both older and newer than the conventional science approach.

"Physics cannot lie; biology usually does". Wad? (find it)

Which one of these two approaches leads to better health for the human population remains open. There is not much good science on either side because the details of husbandry and history of the area would need to be defined to make any findings meaningful. In one sense, conventional fertilizer-based farming has yet to show that the resulting health of people is good enough. That there are "diseases of civilization" is widely appreciated, but the root causes remain obscure. Only the gross parameters are clear – growth, stamina, life expectancy etc. These are good measures. It is to be expected that adequate intake of the major nutrients leads to a strong and abundant population, as it does for any plant or animal. But that does not deal with more long-term or chronic conditions. It remains an open question, whether we can get away for ever, with the simplified ecology of conventional farming. Likewise for the natural philosophy approach, it is not sufficient to label these "organic", when that term is merely legally but not scientifically defined. It is to be expected, on this view of nature, that the synergistic effects of a complex ecology would lead to robust and secure health. The essential features may have to do with over-all health of the soil, as Albert Howard surmised.

The two views of nature are strongly contrasted in this way: the extra-ordinary success of shorting out natural processes, and the more difficult and more all-encompassing science that everything matters. These are viewpoints, from which decisions can be taken. They are equally based on good science. It is not easy for people of either view, to appreciate that the other is in fact sound, logical, rigorous science. The two views are largely incompatible.

The current dissatisfactions with science are mainly biological, or if seemingly in physics or chemistry then as these sciences affect biological matters, including health, farming, wildlife, global pollution etc. The trouble may be that the lessons learnt about scientific progress from physics and chemistry have been rigorously applied to biology. Much spectacular advance has been achieved, yet the time may be ripe for a newer approach, which as it happens would also make science more popularly appreciated and certainly be easier to communicate.

Let me take this thought further.

Is the criterion of good science only that its application works?

Biodiversity research and conservation work, is too often confined to the rare, endangered species only. Yet it is the totality of large numbers of anything that maintains the biosphere.
In particular, too often an individual species is chosen to argue for conservation of some area, eg the spotted owl, when in fact the whole ecosystem matters. The case is that the species indicates the health of the whole. But the effort should incorporate the whole. And the usual argument is really made tongue-in-cheek, prostituting good ecological science.
The problem comes to a head when arguing internationally about policies. Especially in the matter of trade barriers. E.g., the WTO requires scientific proof that an import is damaging and does not accept the ecological reality of the whole.
Thus a renewed 'natural Philosophy' is needed to face and understand reality.

See Mendelsohn, p.79

Scientist might not appreciate (welcome, consider) that it is possible to modulate the current attitude or approach to their subject – there may be more ways to do it. Conversly, non-scientists and especially those who have some antipathy to science, may not consider that it is possible to add or enrich their subjects with a scientific understanding. Their subject would not be diminished as so many believe, but enriched.
One can perceive then a fundamental science which would satisfy a wider and critical audience as well as being a better, more inclusive and more rigorous science.
'Natural philosophy' would maintain the same rigour and peer review of scientific progress, but would extend the limits of its remits beyond that of the immediately relvant fields.
It is difficult to draw the line between such peer-reviewed material of conventional science, and the long experience of observation, which often is anecdotal. There is sound science within the latter; just as there is inadequate science within the former. (say more on this). Note; some languages do not distinguish "experiment" from "experience", eg., French.

Further examples from
Gaia theory

Anti-biotic resistance, see *Nature*

Darwin, pseudo intelligence of nature; cf Karl Popper
Central dogma, virus assembly. Instructions. Making of the individual, Pat Bateson.

Paul Weiss, Goldsmith p.278-9
Waddington
Pat Bateson
Farm Scale evaluations

Barry Commoner

Wonders versus horrors; something deeper than cost/benefit analyses, or side effects.

Other correlates but not the same story:

Reductionist/holistic

Scientific versus spiritual

Enzyme action, Kacser "democracy

DNA gene versus integrated development

Pusztai challenged the cultural attitude to achieve domination over nature.

None of above are more than indicators or symptoms of the more profound distinction based on human instincts – natural and cultural instincts.

The study of nature – natural history – natural philosophy –
All embracing – everything conceivably relevant not only that which is the immediate subject.
Strength of the scientific attitude is to isolate the latter, the better to probe its properties unencumbered and uninfluenced by the apparently extraneous.

The appropriate scinece is ecological scince. Molecular genetics does not have much to say about that. Ecology tells us that mangd sysems like agriculture always become lss able to stand up , become more fragile and less sustainable. That has happened tp farming, and the GM debate has failed to explore the options for the future.
The greater the scietific nderstanding of nature, the more complex and subtle does nature seem to become. Every new scientific application creates more ignorance than it solves.

See “Behind the Polarisation”

Of course, to maintain and increase fertility of the soil, it becomes necessary to study the flow of nutrients throughout the whole cycle, using only bound nutrients and avoiding leaching, and recycling as much as possible. This is very different from current conventional practice, in which nitrate supply leaches out and becomes nitrate pollution.

Natural Systems Agriculture is a new paradigm for food production, where nature is mimicked rather than subdued and ignored. Because we are located in native prairie, we look to the prairie as our model for grain crops. As a result, we are investigating the feasibility of perennial polycultures or mixtures of perennial grains. No other organization has sought to do this. After publishing numerous papers in scientific refereed journals, writing books, and making many presentations here and abroad, The Land Institute receives attention worldwide for its ideas.
The functions of a natural system can be achieved by mimicking its structure. We believe that with additional research, an agriculture that is resilient (and therefore productive over the long term), economical (the need for costly inputs would be significantly diminished), and ecologically responsible is well within reach. The first impetus to search for a new agriculture was soil loss and soil pollution. Agricultural chemicals poison our soils and our waters and harm people. Most importantly, a quarter to a third of our topsoil is gone 200 years after opening this country to agriculture. Natural Systems Agriculture would leave the ground unplowed for years and use few or no chemicals, solving many environmental problems at their root.
The general principle: A central idea of Natural Systems Agriculture is that the structure of native biological communities is the result of centuries of evolutionary selection for ecosystem function. The only communities that persist through evolutionary time are those that:

1. maintain or build their ecological capital,
2. fix and hold their nutrients,
3. are adapted to periodic stress, such as drought and fire, and
4. manage their weed, pest and pathogen populations.

The tendency for our food, fiber, forest and fishery production systems to decline in productivity or require increasing inputs indicates that the structure of these systems is not capable of performing the necessary ecosystem functions.
Where old ecosystems have accumulated ecological capital, such as deep, rich soil, we should look to the structure of the local native biotic community as we design synthetic communities for agriculture and other production systems.

A specific example—Natural Systems Agriculture for the Great Plains of North America. A major goal of The Land

They did not try intentionally to get the better of nature; only to grow larger and better crops!