1

Diversity and sustainability: evolution, information and institutions

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Diversity and sustainability

For many years botanists were puzzled by the presence of certain non-essential chemical substances found within many forms of plant life. These chemicals had no apparent role within the primary production system of the plants; that is, they had no clear link to the organism's growth, maintenance or regeneration. They were termed 'secondary metabolites' to distinguish them from the other, primary productive substances. These secondary substances were a puzzle because it was unclear why they would persist: how could an organism expend some portion of its limited energy on the generation of such chemicals if they played no role in the plant's primary production? Surely other, competing organisms would evolve without such secondaries and supplant them by virtue of relative fitness. Plant communities, nevertheless, clearly do produce many chemical substances that play no direct role in the furtherance of their primary productivity.

The solution to this puzzle was found by broadening the scope of enquiry beyond the narrow focus on primary productivity. Evolution generally rewards the 'relative fitness' of an organism: its capacity to outperform its competitors within the system. One means of achieving relative fitness is the attainment of characteristics which generate individual primary productivity. These are characteristics which perform the fundamental functions of plant life (e.g. photosynthesis, seed production) most efficiently. Primary productivity is thus an indicator of the efficiency of an individual organism with regard to a few of the key functions that every plant must perform. Relative fitness, however, will depend on factors other than individual productivity because the plant must compete within a particular environment, not a vacuum. How well a plant competes depends not only on its individual traits that can be measured absolutely (as in the case of primary productivity) but also on the traits that operate only in relative terms. The survival of an organism will therefore depend in part on its compatibility with the other living components of that environment. For example, many of the secondary metabolites have a positive effect by virtue of their impact on other organisms within the plant's environment. These chemicals may be 'attractors' such as the sweet fruits and perfumes developed by some plants. These contribute to the organism's relative fitness by increasing the rate of dispersal of its pollen or seeds. Other chemicals are more of the nature of 'repellents': defence mechanisms to guard against the plant's predators and competitors. In either case the chemical is given effect by virtue of its action on other organisms within the environment, not in isolation.

These 'secondary' characteristics of a plant are equally important to the survivability of the organism within its environment as are the 'primary' ones. The primary characteristics are more fundamental only by virtue of their greater 'generality'. Primary characteristics are given effect irrespective of the environment in which they exist; they are more general in the sense of their greater context-independence. Secondary characteristics on the other hand are valuable to the plant because they are effective given a particular set of conditions; the presence of a particular pollinator or predator, for example. A secondary characteristic that contributes hugely to fitness within one environment may have little or no effectiveness in one slightly different. Characteristics are 'primary' only in the sense that they are effective across more environments than are secondary characteristics; both are equally effective in contributing to relative fitness.

The relative benefits from generality are meagre. It is primarily useful for purposes of comparability; that is, it is possible to compare primary productivities across organisms and across environments because the same function is being performed under a wide variety of circumstances. There is no relative fitness obtained by plants from generating comparability across environments, therefore plant communities have also produced a wide variety of context-dependent characteristics that contribute to their survivability. There is no obvious comparative advantage to be garnered from generality in traits, and so there exist both forms of characteristics within plant communities: primary and secondary.

This is probably counter-intuitive. It might seem that the organism which achieved a greater proportion of widely-effective (primary) traits would be the more successful across time with varying conditions; that is, it seems intuitive that primary characteristics might be favoured in the pursuit of survivability. In fact, it is the opposite situation that is observed to be the case in plant communities; it is now being hypothesised that the most successful plant communities in terms of long-term survival are precisely those with a greater proportion of secondary characteristics (see Fellows and Scofield, this volume). These characteristics provide usefulness with regard to relative fitness under locally prevailing conditions and they also contribute to success on a long-term basis by providing a wider range of characteristics on which to draw in the event of a sudden large-scale shift in the physical environment. Therefore, diversity in production techniques is now seen to be important for both local and long-term survivability within plant communities.

One of the themes of this volume is to draw the parallels between what has been found to be important for survivability within this evolutionary strategy used in plant communities and that which is important for sustainability within human society. Do we need to learn to apply the lessons learned from observing the mix of primary and secondary strategies existent within plant communities?

In the first instance, it is necessary to ask whether there are forces to create the right mix of primary and secondary characteristics within human societies, as there are in the plant communities. That is, why would the human community place a different emphasis on the two forms of production strategies relative to plant communities? The answer lies in the human capacity for communication, and the importance of communication in human production. Unlike plant communities, human societies do have the need to seek comparability across communities and environments. In many cases such comparability is a useful strategy because it allows these human societies to better 'network', thereby achieving returns to communication, trade and scale. For these reasons human societies have a relatively greater tendency to focus on generally applicable strategies (analogous to primary productivity) to the exclusion of those environment-specific strategies that would be suited to the prevailing conditions in the locality (analogous to secondary characteristics of plants).

The homogenisation of the biosphere and the consequent threat to biological diversity is a by-product of the more general forces within human society toward increased standardisation and uniformity (see Swanson, this volume). With technological advances in the areas of communication and transport, that heterogeneity which has existed in the past is receding in the face of the increasing standardisation of systems of production, communication, institutions and even knowledge. This is causing the secondary characteristics (or cultural diversity) across human societies to recede in the face of the pursuit of the primary. Of course, even the biological world is now a component of the 'human world', in the sense that its make-up is determined in large part by human choices. Human societies continue to exercise this discretion in order to convert the biosphere to the same set of standardised (domesticated and cultivated) species across the globe. Thus, the forces for increasing homogeneity in human society are seen at numerous levels: cultural, institutional and even biological.

The general themes of this volume are two: should human societies adopt a more diverse set of production strategies and, if so, how should they go about doing so? The parable of the secondary metabolite provides the answer to the first question; sustainability is dependent in part on the pursuit of strategies that are diverse and environment-dependent. The answer to the second question is more complicated, given the nature of the human species and human societies. In short, there are profound and important forces within human society for the standardisation of many facets of the human world in order to aid communication and cooperation within the species; it is difficult to conceive the means by which the importance of diversity may be brought to bear as against these broadly operating forces.

Irrespective of whether human societies should place more emphasis on diversity for purposes of sustainability, it is clear that they are in fact stating that it is their intention to do so. The Convention on Biological Diversity adopted in Rio de Janeiro in 1992 represents an attempt by the human species to come to terms with the costliness of its single-mindedness about primary productivity and its negligence concerning the values of diversity. It states that biological diversity must be conserved, and that cultural and institutional diversity must be respected. The really difficult questions concerning the effective conservation of biological diversity relate to the necessity of operating at all of these levels simultaneously: institutional, cultural and biological. How is it possible to conserve diversity in the face of opposing forces operating generally across human society at all of these levels?

This volume develops these themes within the context of a case study of the pharmaceutical industry. This case study was chosen because it brings us full circle, back to a focus on the values of secondary metabolites within plant communities. This time, however, the usefulness of these secondary chemical substances is being considered from the perspective of the human rather than the plant community, with respect to the medicinal uses of secondary metabolites. The pharmaceutical industries are in the business of developing the usefulness of chemical substances with demonstrable biological activity within humans. The purpose of secondary metabolites in plants is to make an impact upon other organisms, chiefly animals, and so their usefulness in the pharmaceutical industry is easily deduced and long utilised. Until recently in the development of human pharmacology, almost all identifications of useful chemical activity came from this source; modern pharmaceutical industries had their origins in the earlier herbalists. The analysis of these values is one of the primary objectives of this volume. In short, the question concerns whether there exist real, concrete (secondary) values flowing from the retention of biodiversity for medicinal purposes that might be used to counterbalance the (primary) values flowing from global homogenisation that are threatening it.

The second theme of the volume is the nature of the changes that are required to address this facet of the biodiversity problem: how is it possible to incorporate these values of biodiversity into human decision making concerning its retention? If human communities persist in the conversion of lands in the pursuit of enhanced primary productivity, and without consideration for the secondary values of diversity that are foregone in the process, then the ultimate conclusion is unavoidable: the value of biodiversity to the pharmaceutical industry will be lost. The calculation of the benefits from further conversions must be made to incorporate these secondary as well as primary values. How is this to be accomplished? One possibility is to recognise that the homogenisation of the biosphere is a by-product of the homogenisation of human societies, and to operate at this more fundamental societal level in order to resolve the biological problem. It is standardisation across human communities in regard to systems of production, knowledge and finally institutions that results in the disregard for the special adaptations of local resources. If the values of these environment-specific characteristics are to be brought within the human calculus, then human systems must first be made heterogeneous enough to recognise and incorporate these values. The problem of biological diversity, therefore, requires a long, hard look at the biases towards uniformity within human societies and human systems generally. It may be necessary for human systems of knowledge and institutions to become more tolerant of heterogeneity before the people 'on the ground' making conversion decisions will be caused to appreciate its value within the biosphere.

The remainder of this chapter develops this idea of the conflicts between the objectives of uniformity and diversity across evolutionary, informational and institutional systems. It makes the case that *global* institutions must be developed in a fashion that takes into consideration the heterogeneity in *local* conditions. Global institutions must be made diverse enough to take local conditions into account and to value them; otherwise there will be an implicit bias toward the conversion of local conditions to fit global institutions.

The specific issue addressed by this volume is the controversial one concerning the nature of the property rights system that is required to bring the values of biological diversity within human decision making. The conclusion of the volume is that internationally-recognised property right systems must be flexible enough to recognise and reward the contributions to the pharmaceutical industry of each people, irrespective of the nature of the source of that contribution. In particular, if one society generates information useful in the pharmaceutical industry by means of investing in natural capital (non-conversion of forests, etc.) whereas another generates such information by investing in human capital (laboratory-based research and school-based training), each is equally entitled to an institution that recognises that contribution. 'Intellectual' property right systems should be generalised to recognise the diverse sources of useful information, not only 'intellectual' but 'natural' as well. Diversity in institutions is a prerequisite to the retention of diversity in our natural world.

The purpose of this introductory section has been to demonstrate very generally the manner in which fundamental trade-offs exist between diversity and uniformity – at several different levels: biological, cultural, institutional. These trade-offs are further explored in turn in the remainder of this introductory chapter. In regard to biological diversity, we will return to the distinction between plant and animal communities and the implications for diversity emanating from this distinction. With respect to cultural systems, we will examine the diverse sources of useful information supplied to human communities (intellectual and natural), and the friction between the usefulness of this diversity and the need for uniformity in processing and analysing the new information. Finally, we turn to the institutional systems used by human societies to regulate the production of information and ask why the system is not operated more inclusively as 'informational property rights', rather than the more restrictive 'intellectual property rights', in order to recognise the diversity of sources of useful information. In this case the conflict between diversity and uniformity seems to be based in the misconceived notions of own-interest rather than real trade-offs. In order to regulate the trade-off between diversity and uniformity where it really exists (at the biological and cultural levels), human institutions must first be transformed in a fashion that recognises diversity and values its contributions to the sustainability and productivity of society.

Diversity within evolutionary systems

As will be developed further in the chapter by Fellows and Scofield, there is a fundamental trade-off for fitness purposes between the production of primary and secondary metabolites within plant species. Secondary metabolites were long-recognised but little understood because the evolutionary benefits from a non-productive chemical substance were not appreciated. The explanation that has been given is that coevolution between species within a predator–prey system generates the usefulness of such substances. Primary productivity can aid survivability but only to the extent that it makes the organism a better competitor within its environment. The capacity of the species to function within a system is actually the more fundamental criterion for success; primary productivity is only useful to the extent that it contributes relative to this framework. Secondary metabolites fulfil this purpose because they are effective precisely by reason of their attunement to their environments.

Secondary metabolites are usually effective by means of attracting responses from other organisms that might enhance its relative prospects for survival or by repelling those responses that might diminish its chances. Fruits for example, promote the response of other organisms that serves the purpose of seed dispersal. Other chemicals are bad-tasting or toxic in order to provoke the desired response from predators. The category of substances within plants that have these effects on animals are known as 'alkaloids'. By their definition the alkaloid group of chemicals are biologically active because they exist in order to provoke responses from animals. The known biological activity of these substances is the information that is useful to human societies; it eliminates the need to conduct trials or to develop scientific methods for the identification of such chemical activity. Obviously, for a chemical to be a potentially useful medicinal substance for human use, it must first be found to have some activity within the species.

It is not happenstance that plant and other communities have developed such substances; it is their manner of communicating between species. Secondary metabolites establish communication between plant and animal communities by generating the desired response from the particular organism. Animals have developed a wider range of interaction primarily on account of their greater mobility. Plants must perform these same functions through chemical production: 'plants produce, animals act'. Plants communicate to animals in order to elicit the response that aids their survivability by means of specific chemical production. In this manner plants follow strategies that allow them to adapt to their specific environment (that is, the predators and others within it). This 'dual' primary/secondary strategy of plants is successful because the production of biologically active ingredients creates a complex web of interaction within the particular system of which the organism is part.

Human societies also form complex webs of interaction (see Wood Sheldon and Balick, this volume). The primary distinction is that because of our evolved capacities for communication, most of that interaction is focused on other humans and a small number of closely associated species. Our comparative advantages in communication and mobility have led us to be unmindful of the need to adapt to the local environment as it is presented (the approach of the relatively immobile and uncommunicative plants). Instead we focus on the few organisms with which we have established a cooperative relationship, and we ignore the communicative and cooperative potentials of most others.

We are thus a species that focuses on generally applicable primary productivity to the exclusion of most other forms of interaction. This has an obvious cost in terms of foregone values; for example all of the potential communications from plant–animal relationships coevolved over hundreds of thousands of years are lost with the conversion of a forest in pursuit of an increase in agricultural commodity yields.

Why should human society learn to appreciate and incorporate heterogeneity within its systems of thought, production and cooperation? This is what the human species should learn from the continued existence of secondary metabolites within plant communities. An exclusive focus on a few primary characteristics that contribute to success may not be a good guide to ultimate survivability. Sustainability requires not only the pursuit of general characteristics of primary productivity but also the incorporation of specific characteristics conducive to environmental adaptation.

How can adaptation be incorporated as a criterion within societal decision making? The pursuit of primary productivity by human society goes hand-in-hand with a bias toward homogeneity within human systems, cultural and institutional. It is this broad-based pursuit of the primary to the neglect of the secondary that makes considerations of adaptability complex. The incorporation of a criterion of adaptation will require the incorporation of diversity across all of these systems simultaneously.

The lesson to be derived from the analysis of plant communities is that a strategy that combines both primary and secondary values is best for survivability. Ironically, it is our unwillingness to learn from these communities that has prevented us from recognising this point, and has led to a broad-based underappreciation of these organisms and has also led to the threat of their extinction.

Diversity within informational systems

The information generated by the secondary processes within plants is useful to human societies. The starting point for the creation of any pharmaceutical product must be a template of known biological activity (see Albers-Schönberg and Aylward, this volume). Then the task is to identify a useful purpose for that activity, or to develop that activity along a channel toward some useful purpose. In either event it is the known biological activity of a chemical substance that must be the starting point of the exercise. The secondary metabolites within plants have long provided a glossary of such templates, and continue to provide such information.

This is not to say that there are not other sources of such information. Many of the more recent discoveries of biologically active substances have derived from the screening of microbes rather than plants. In addition, there are now claims that 'rational design' is capable of performing many of the functions formerly performed by secondary substances (see Aylward, this volume). Nevertheless, it is true to say that many of the original templates of biological activity were derived from nature, and there are doubtless many more yet to be found. The secondary metabolites resulting from coevolution are an important informational input into the pharmaceutical industry.

There is another form of coevolution that also generates useful information: the inter-relationships between plant and human communities (see Wood Sheldon and Balick, this volume). It is still the case that 75–80% of the human population relies on locally-derived medicinal systems based on natural ingredients (see Brown, this volume). The usefulness of this history of use is indicated by the fact that laboratory analysis has found that nearly all of those natural ingredients utilised by local communities do in fact register some sort of biological activity. The use of this 'ethnobotanical' information when screening plants for biological activity has increased the rate of discovery by 400–800% (see Brown, this volume). Hence there is a lot of useful information available both within the plant communities and the local communities using them.

Despite the demonstrable value of these forms of information, the globalisation of Western-style medicine continues to reduce the number of peoples practising diverse forms of medicine, without incorporating their knowledge into the prevailing system in many cases (see Khalil, this volume). Once again this is the result of a conflict between the forces of uniformity and diversity.

The problem lies in the requirements of uniformity in scientific method. Demonstrated effectiveness of chemicals must be accomplished within Western science by means of a structured causal analysis, showing each of the links between input of chemical ingredient and accomplishment of its object. To be accepted as scientific knowledge each of the steps in the chain must be demonstrated both analytically and in laboratory testing. The purpose of such a requirement is logically obvious: it requires that knowledge be built incrementally upon a common framework so that all scientists are able to understand and replicate the activity within a homogeneous environment (that is, the chemists' laboratories).

The information communicated between coevolving plant and human communities does not fit neatly within the existing framework of medical science. It is acquired instead from a history of experience and clinical trials. Hence, the chemical substance and its human effectiveness are known, but not the intermediate steps in the chain of causation. This is information that is useful, but not respected under the existing methods of science (see Brown and Khalil, this volume).

The issue is whether uniformity in the scientific method is necessary for scientific credibility or simply useful for scientific interaction and efficiency. If uniformity in method is an absolute necessity, then some standardisation will be required; however, if it is only an aid to efficiency (by means of aiding communication and interaction between scientists working in homogeneous environments), then scientific method should be required to be heterogeneous enough to absorb all useful information within this system of knowledge.

It should first be mentioned that historically such uniformity was not made a requirement for the acceptability of useful information. The practice of natural-based medicine throughout the globe until just a few decades ago bears witness to this fact. For example, lemons were used as a treatment for scurvy for 200 years prior to the identification of vitamin C and its mechanisms. The use of the bark of the willow tree (salicylic acid) was in use for pain relief for hundreds of years before either its current form (aspirin) or precise function were known (see Albers-Schönberg, this volume). It was not until the initial developments in microbial-based research that laboratory work became the standard practice in Western medicine. Even today fundamental procedures (such as the application of general anaesthesia) are used without any understanding of the mechanism by which they operate.

Western-style scientific method in this area has been standardised only