

# THE HISTORY OF NATURE

MARK LAWLEY

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## INTRODUCTION

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WE ARE CREATURES of our time. What we see and what we overlook, how we think and how we do not are consequences of the circumstances in which we grow up and the ideas we encounter, rather than of our genetically inherited attributes. Whereas the abilities and life-styles of other species are written in their genes (sun-loving plants, for instance, cannot thrive in shade), nurture is ever a stronger force than nature in determining the bent of a person's mind.

There have been three main historical phases in how people have perceived the living world around them. During the first phase, which lasted until the 16th century in western Europe, people were concerned mostly with how nature affected their lives from day to day. Their anthropocentric world was one of personal experience and practical immediacy; they had no idea that living forms and events varied over large distances or during periods of time far longer than individual human experience.

During the second phase, anthropomorphic attitudes to nature arose as humankind gained a measure of control over environmental vicissitudes. Naturalists of ancient civilizations, the Renaissance, and the Enlightenment collected animals and plants and classified them according to their

forms and structures. Life was substance rather than process (Chapter 1). In western Europe the comfortable classes of the 16th century and thereafter greatly enlarged their spatial perspective of nature, as microscopes opened up a new world of diminutive species and international travellers discovered many additional kinds of animals and plants. But nature still lacked a temporal dimension. It had no history.

Then wholesale economic and social changes in western Europe during the late 18th and early 19th centuries revolutionized the world of ideas and the ways in which naturalists interpreted natural forms and events (Chapter 2). This third phase of how people interpreted nature began when they discovered that the world was far older and that nature had changed over much greater periods of time than had previously been supposed. Lamarck, Cuvier, Erasmus and Charles Darwin, and Charles Lyell arranged natural forms and events in time as well as space. As nature's history came into view, life became process, not substance.

During the 19th and 20th centuries, biologists studied the three universal temporal processes of organic development – growth of individual organisms, evolution of species, and secular successions of communities of animals and plants. Naturalists, on the other hand, remained more interested in nature's spatial arrangements, such as species' geographical distributions and favoured habitats, and studied processes such as feeding and breeding only during limited periods of time. Even the relatively short-term tasks of elucidating species' life-cycles require more patience than many naturalists can muster.

During the 19th century, natural history parted from a recently institutionalized biology based in the laboratory, and by the 20th century also found itself divorced from the new field-science of ecology (Chapter 3). Meanwhile, professional biology had become dominated by investigation of what happens inside organisms, how it happens, and how it affects organisms' behavioural characteristics (Chapter 4). Observing and describing succession and evolution were and remain more protracted, expensive, and uncertainly rewarding than laboratory-based pursuits such as genetics and immunology.

Biologists and naturalists alike recognize that growth, evolution, and succession share features of energetic performance (Chapter 5), but often confuse material changes during any one of these processes with changes

caused by either of the other two. Naturalists may distinguish growth, evolution and succession more accurately in future by studying how organisms, species, and communities change during time as well as in space (Chapter 6).

From the 19th century to the present day, man's understanding of how nature changes with time has enabled him to interpret nature in a manner much more detached from human needs and values, in less anthropocentric or anthropomorphic ways. People know that humankind has existed only in comparatively recent times, an addendum to rather than the centrepiece of life on Earth, just as the Earth is no longer the centre of the universe, around which stars and other planets revolve. But natural history did not become completely detached from human affairs in the 19th and 20th centuries, any more than anthropomorphic interpretations of landscapes and living forms had earlier eradicated anthropocentrism. Modern man is as keen as his forebears were to enhance his well-being by controlling his environment, and proclaim his social status through familiarity with and appreciation of that environment: conserving wildlife, habitats, landscapes, and townscapes; gardening; breeding and keeping pets. These environmental interests all remain more popular than grubbing about in the countryside for economically insignificant wild species. Moreover, just below this anthropomorphic attitude to nature lurks the still more primitive anthropocentrism of the mediaeval mind. Truly does the man of today yet see himself centre-stage, on a pinnacle of progress, at the apex of evolutionary attainment.

## I. NATURAL HISTORY BEFORE THE 19TH CENTURY

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ONCE UPON A TIME, long ago in prehistory, everyone was a top-of-the-range naturalist. People knew which kinds of animals and plants to eat, which might eat or poison them, which caused or cured illnesses, healed wounds, and which could be used for making clothes to keep warm, dwellings for shelter, and tools and other artefacts. Natural selection honed peoples' abilities to recognize similarities and distinguish differences between organisms, for their prospects of surviving and thriving depended on how many kinds of animals and plants they could identify, and whether they knew which caused harm and how others could be used to advantage. The world relentlessly bore in on them from every direction, so their view of it was anthropocentric. Life was too much of a constant struggle to survive to regard nature as anything other than elemental forces to be exploited or avoided.

Successive civilizations appeared on the world's stage and passed into oblivion, each with its smattering of naturalists, from Aristotle (384–322 BC) in ancient Greece to Aldrovandi (1522–1605) in late Renaissance Italy. By the 16th century the more favoured specimens of humankind in western Europe found themselves less buffeted by the rigours of nature. Fear

of their environment and acts of survival no longer filled every waking moment. Periods of leisure provided opportunities for curiosity about and reflection on the world in general. Perceptions of and attitudes to nature altered accordingly, alongside long-established anthropocentric attitudes and superstitions which continued to dominate uneducated minds. Invention of the microscope and increased international travel brought to notice a far greater range of animals and plants than had been known hitherto, so people with sufficient resources and spare time to reflect on nature began to see it in a spatial perspective which extended beyond the limited experiences of each person or community. As people gained more and better control over nature, they began to think of natural forms and events in anthropomorphic terms (Thomas, 1983), as fashioned by human influence rather than as extraneous forces which threatened their well-being – not only domesticated animals, crops, ornamental plants bred for the garden, cultivated landscapes and townscapes, but also less tamed landscapes and the wildlife therein.

Appreciation of natural history resurged among the upper classes in late 16th century Italy (Findlen, 1994), and spread across western Europe in the 17th and 18th centuries. For the comfortable classes of the time, demonstrating one's ability to control nature without having to work to do so had become a potent symbol of social superiority. Natural history therefore represented the essence of refined taste, a pastime suitable for the upper echelons of society. By taking it up, those lower down the social order aspired to join the elite, if not materially in this world, then at least spiritually in the next.

While workaday naturalists remained preoccupied with how animals and plants affected their livelihoods, the intelligentsia interested themselves in the features and behaviour of species. But pre-industrial naturalists only studied how organisms change during their lives. They had no inclination to study how and why natural forms and events change over longer periods because they knew of no reason to suppose that landscapes and species had looked or lived differently in the distant past. Right up until Linnaeus's day in the late 18th and even into the early 19th century, naturalists of working and comfortable classes alike regarded the natural world as unchanging, just like contemporary, agrarian, pre-industrial society. Seasons came and went, each year much

like the last, save for fluctuations of famine and disease, plenty and prosperity.

This view of the natural world as unchanging owed its prevalence to an equivalent rigidity of pre-industrial society. The circumstances in which someone was born determined his prospects for life. A labourer could not cheat his fate, while the landowning rich stayed rich. A person could enter the aristocrat's world of power, privilege and patronage only at birth. Everyone knew their social station, and kept to it. Likewise in the natural world, species were all perfectly conceived, constant and enduring, easily distinguishable, satisfying to collect and arrange, as well as to describe and classify.

Naturalists neither sought nor found any flaw in a pervasive ideology insisting that God was the father and arbiter of diversity in nature, spawned by His wonderfully fertile imagination in a six-day spree at the start of time. Moreover, on the first day of its existence each species looked exactly as it does now, for not only had all species come into existence simultaneously, they were also perfectly adapted, created inviolate, immutable, and destined to remain so. Provided with a celestial cause and its incorruptible consequences, naturalists contentedly gathered and classified the fall-out from Big Bang. Their sole duty was to catalogue The Almighty's work by identifying, describing and classifying species. Priests pottered round their parishes compiling inventories of the Good Lord's largesse. Natural history gloried in its holy alliance.

For naturalists before the 19th century, the 'history' of nature referred merely to descriptions of its visible forms. They had quite enough to do identifying and describing the more accessible and conspicuous animals and plants – vertebrates, large invertebrates and vascular plants – without wondering how or why these organisms exist and persist. They had no idea that nature changes as time goes by, and no more saw a connection between the visible features of natural objects and their origin and development in the past than had the illiterate hunters and farmers of prehistory. No one imagined that species had been and still were evolving from and into other species at varying times and tempos. The existence and nature of their histories remained unsuspected, beyond the scope of contemporary thinking or even imagination.

## 2. NATURAL HISTORY AND BIOLOGY IN THE 19TH CENTURY

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THROUGHOUT HISTORY, what people have seen in nature and how they interpreted and studied it have been as much influenced by contemporary social and economic habitats as by the lore of wisdom accumulated by previous generations.

Linnaeus, for example, lived in a pre-industrial world where the ceaseless rhythms of nature impinged on the human mind as insistently as the pulsating din of machinery was to do so subsequently. It seemed to pre-industrial naturalists that landscapes and species had always been as they were then, and would remain so for evermore. But late in the 18th century the Industrial and French Revolutions disrupted the age-old rhythms of agrarian society. Nature no longer seemed set in its forms and ways. It became obvious that human society and the natural world were equally susceptible to convulsive change when the Industrial Revolution in England and Scotland began to harness new sources of energy, providing unprecedented impetus for social and economic development in a new industrialized world. At the same time, the French Revolution overran the social laws propping up the old regime, breaking the medieval mould of inherited power and privilege. Together, these two revolutions relaxed con-

trol of old commercial opportunities and created new ones, channelling the wealth of a very few into the hands of an unprecedentedly populous, affluent and aspirant middle-class multitude. Henceforth, any determined working or middle-class man could improve his lot by his own effort. Both revolutions – the one British and economic, harnessing new sources of fossil fuel in new ways; the other French and social, redistributing resources – not only profoundly influenced peoples' life-styles, but also dislocated their mental worlds from the traditional routines of pre-industrial society and changed the manner in which they studied and interpreted objects and events around them. The aims and practice of natural history in this period changed as rapidly and irrevocably as the lives of natural historians.

The increasing prominence and influence of the middle class were not only important causes and consequences of the British Industrial and French social Revolutions, but also stimulated unprecedentedly widespread interest in natural history and science. Thus, a suddenly burgeoning middle class benefited most from the wealth generated by industrialization, and welcomed new concepts of how and why the natural world changes with the passing of time as enthusiastically as they embraced changes to contemporary social order. Unprecedented numbers of the educated classes were taking keen interest in the long-running tasks of collecting and describing species, elucidating their life-cycles, and classifying them according to their evident similarities. These classifications prompted discussion of the causes of such natural similarities; men like Buffon and Erasmus Darwin floated evolutionary theories about temporal changes in nature. But the Anglican Tory ruling class in England was too well entrenched to surrender its power in the late 18th century. Moreover, the French Revolution and its aftermath of economic austerity deterred innovative entrepreneurial activity, both on the Continent and in Britain, as well as any spread of liberal theories about social and natural development. The time was not yet quite ripe for the iconoclastic intellectual revolution which was to become an inevitable consequence of the economic and social revolutions.

Indeed, the enlightened years of the late 18th century, which saw Gilbert White's *Natural History of Selborne*, Birmingham's Society of Lunatics (free-thinking industrial barons interested in natural science), Erasmus

Darwin's erotic poetry and evolutionary prose, and a great increase in the popularity of dissenting religions and liberal Whiggish politics had given way by the early years of the 19th century to an era of austerity as the Napoleonic Wars checked any prosperity stemming from a still embryonic Industrial Revolution. This austerity banished the material atheism which had thrived during the affluent Enlightenment, and stifled any immediate prospect of liberal thought or technological development. God was once more in demand to shore up a fragile social hierarchy. The collapse of the French empire following the final defeat of Napoleon in 1815 opened up the Continent to freer travel and trade. But in the 1820s Protestant England was still steeped in religious and social attitudes deriving from Henry VIII's purge of Catholicism and the Civil War in the 17th century, leaving it far less sympathetic to liberal social policies or biological theories of organic development originating from the Continent than was Scotland, where Jacobite sympathies lingered on.

Not until the 1830s did industrial growth and social reform gather sufficient momentum to break the old regime's stranglehold of privilege and power, and kindle disconcertingly iconoclastic theories about the origin and development of the natural world. In Paris the lid blew off an argument between Georges Cuvier and Etienne Geoffroy St Hilaire about whether species share features of form (and may therefore have originated from common stock) despite their diversity. This controversy marked a definitive parting of ways between natural history which distinguishes species by their differences and unique features, and natural science which regards species as comparable. Like Linnaeus before him, Cuvier regarded species as unchanging and disparate, consistent with a conservative attitude to human society, whereas for Lamarck and Geoffroy grouping species according to their similarities was a prelude to tracing their putative evolutionary origins. This notion of species transforming into new types was enthusiastically adopted as an ideological justification for reforming society.

In Britain, as the Reform Laws began to loosen the Anglican Tory hierarchy's grip on power and privilege, the benefits of industrial developments started to filter widely through the middle classes. With their new affluence, many more people took up natural history, and interest in evolutionary ideas and the laws of living nature spread from the Continent to

Britain. For these reasons the second quarter of the 19th century was as pivotal a period in the development of natural history as in the political and economic development of western Europe.

Before the Industrial Revolution people had no idea how old the world was, and the notion did not exist that landscapes and species had forever been changing. Their extant forms were presumed fixed and eternal. Even changes in organic form and occurrence during very brief periods such as the life of an individual organism were poorly understood. As late as the mid-17th century, for example, people thought that adult insects arose spontaneously from decaying organic matter. Only subsequently did Swammerdam and others discover that they develop from egg to adult, and back to egg. Similarly, at the end of the 18th century Gilbert White was still uncertain about whether swallows changed their form in winter, or where they spent it. Seasonal and secular succession were prominent features of wildlife, agriculture, and in gardens. But no one had proposed any cause which might convincingly explain these effects. Many of the life-cycles of individual organisms had only recently been elucidated at the beginning of the 19th century. Moreover, not until the closing years of the 18th century did people begin to realize that landscapes and species may no longer look like they had in the distant past.

Whereas pre-industrial agrarian civilization had mainly drawn a living from the earth's surface, industrial activity burrowed into it, and greatly increased the rate at and extent to which rocks beneath the earth's surface became exposed to view. More mines were sunk. Canals, roads, and later on railways were quarried through rocks in the landscape. Well before the mid-18th century, geologists had realized that younger sedimentary rocks overlie older strata. But this evidence came from mine-shafts at unconnected locations. Not until excavations for the construction of canals during the Industrial Revolution had exposed strata for considerable lateral distances did geologists see the spatial and perceive the intellectual connection between geological strata at different locations.

At the same time, in late 18th century England, philosophical societies arose which enabled people to discuss discoveries and exchange ideas. This social mechanism for the communication of ideas mirrored lateral geological links between localities: the previously disparate became connected, and the connected were disseminated.

This new, joined-up, stratigraphical theory was not only valued for its intellectual beauty. It also assumed a vital commercial application when William Smith realized that many strata could be unambiguously identified by their fossils, which were identical in different places. And since the occurrences of some strata were known to be correlated with the presence of coal and other valuable ores and minerals, these newly recognized clues in the rocks enabled geologists to predict much more accurately where such commodities might be found, and search for them less expensively.

In the new Industrial Age it also became apparent that the durability of rocks and the angles of inclination at which strata lay strongly influenced the contours of the countryside they formed. Thus, both the history and present features of landscapes suddenly became explicable in terms of their underlying structure, as it was later to become clear that the histories of living organisms lay hidden and encoded in tissues beneath their external surfaces. And just as the forms of landscapes have changed out of recognition during aeons of time, might not those of animals and plants have done so too? In geology and biology alike, it dawned on naturalists that temporal classifications of rocks and organisms underlay – both literally and metaphorically – descriptions and classifications of their visible features and compositions, and that these temporal classifications were likely to be far more intellectually absorbing than spatial classifications of form.

As the 18th century gave way to the 19th, an unprecedentedly rapid control of energy during the Industrial Revolution and redistribution of wealth after the French Revolution began to accelerate the pace of change in most aspects of European life, creating a state of mind much more receptive to the notion that all organic and inorganic nature might be changing with the passage of time. When naturalists born at the dawn of the 19th century came of age, their outlook on the world began to replace their forebears' more conservative views of nature. At just the time in the intellectual development of the western world when it was becoming old-fashioned to insist on the temporal fixity of forms, and the notion that landscapes and species had existed unaltered since the start of time began to falter, natural historians were no longer exclusively preoccupied with describing organic and inorganic forms in nature at the present, but beginning to realize that these changed with the passage of time. Revolutionary

times breed further revolutionary ideas; the industrial and social revolutions in western Europe in turn made Lyell, Darwin, and their contemporaries realize that inorganic and organic nature may have always been changing too. And their new temporal perspective of nature kindled their quest to distinguish cause from consequence in the countryside.

Being a pastime, interest in natural history fluctuates in accordance with standards of living, ebbing with the onset of austerity, and flowing again with the resurgence of prosperity. In Britain, the popularity of natural history is as good an indicator as any of prosperity in the middle class. As the Industrial Revolution gathered momentum in the 1820s, new manufacturing processes controlled huge quantities of fossilized energy at an unprecedentedly rapid rate, far faster than it could be dissipated in the essential domestic needs of everyday life, even by a rapidly increasing population. A *nouveau-riche* middle class arose with large disposable incomes, the personal wealth of whose members sometimes approached that of the old-established land-owning gentry. This new bourgeoisie not only became increasingly secure financially, but also literate and leisured, with the time, energy, and means for indulging itself in luxurious pursuits. Since both literacy and leisure are handmaidens to an informed study of nature, natural history became an ideal pastime for the middle classes, whose members greatly swelled the ranks of amateur naturalists.

As exciting incentive, there still remained, early in the 19th century, the prospect of discovering close to hand species of vertebrate animals and vascular plants new to science, and elucidating previously unknown details of their life-cycles. Naturalists had for some time past been studying the life-histories of species by watching them grow and mature in their native haunts; the more inquisitive naturalists also took their finds home and 'grew them on' in the conservatory in order to discover and describe how they change as they pass through their lives. Scientifically minded naturalists even experimented by altering and controlling the conditions in which they reared their pets, in order to see how environmental circumstances affected their development. In these ways the naturalists of yesteryear laid an essential foundation for subsequent developments in comparative anatomy and embryology.

Increasing travel and communication, together with the widening public appeal of natural history quickened the discovery and description

of species, and as the 19th century came of age, naturalists had broken the back of their long struggle to discover, delimit, and classify the more accessible and conspicuous species. With the flow of unknown European vertebrates, large invertebrates, and vascular plants slowing to a dissatisfying trickle, naturalists began to look for new challenges. Thus, the first two or three decades of the 19th century were a watershed for European natural history, for although the filling of herbarium-sheets and collecting-cabinets continued to satisfy the incorrigible acquisitiveness and enlarge the experience and expertise of individual naturalists (just as familiarity with a wide range of species had formerly enhanced their ancestors' prospects of thriving), it no longer quenched that intellectual thirst which drives the search for new discoveries to extend the frontiers of corporate, cultural knowledge.

And so, by the second quarter of the 19th century, the swelling ranks of a bourgeoisie interested in natural history found the prospect of discovering species of vertebrates and vascular plants new to science baulked by a dwindling supply of such species close to home. However, there remained innumerable undiscovered species of small invertebrate animals (which lack backbones) and cryptogamic plants (which lack flowers) to describe anew. Some naturalists could now begin to seek these down the microscope, for not only had the Industrial Revolution's socio-economic consequences precipitated unprecedented awareness of process and change in the natural world, it also altered the ways in which nature could be studied.

New and rapidly developing industrial techniques for precision-engineering and mass-production of glass and metals greatly improved the quality and reliability of microscopes and ancillary equipment, as well as bringing them onto the market at prices an increasingly affluent middle class could afford. J.J. Lister's work on achromatic lenses in the 1830s eliminated the distortion caused by looking through two lenses in series in compound instruments, opening up for amateur naturalists a vista of diminutive organisms and fine organic detail, enabling them to discover and describe far more than had previously been known of invertebrates and cryptogams. For previous generations, glimpses of this microscopic world had been accessible only to pioneering scientific entrepreneurs such as Leeuwenhoek, Swammerdam, Malpighi and Grew, or their rich patrons.

Now anyone with a few pounds to spare could own a microscope giving a previously unattainable quality of image which enabled them to study tiny animals and plants.

Moreover, just as microscopes became better, cheaper, and more easily obtainable in the 1830s, the introduction of steam-presses enabled books to be printed more cheaply, bringing the literature of natural history within reach of middle-class pockets as well as adorning the shelves of libraries at upper class country seats.

By spawning a middle class imbued with the ethic of work and invigorated by first-hand experience that effort could and did bring material reward, the Industrial and French Revolutions created a new state of mind in people prepared to try and earn a living from investigating the mysteries of the living world. Just as studying the forms and structures of rocks had unexpectedly facilitated the harnessing of immense industrial resources, might investigating the external forms and internal anatomies of animals and plants bring equivalent rewards?

But the prospect of earning a living was anathema to a landed gentry which had acquired its wealth in a bygone era, and now languidly reposing at inherited entitlements in the shires. Familiarity with empirical science implied a propensity for trade, manual labour and the soiling of hands, whereas for an Anglican elite educated at 19th century Oxbridge, ability to quote classical Latin and Greek literature remained the surest sign of good breeding and upbringing – an educational atavism harking back to the Humanist revival of the Renaissance when scholars had rediscovered ancient texts, and regarded them as the fount of knowledge and cornerstone of culture. Consequently, scions of 19th century gentry infiltrated only those middle-class occupations considered compatible with a classical education, and which enjoyed social standing while requiring but modest professional effort – the priesthood, law, architecture.

The upper classes had taken up natural history as an eclectic interest which demonstrated their control over wild nature and their own lives. This prompted the middle and lower classes – who had to work for a living – to sublimate a yearning for the gentry's unattainable, leisured life-style by aping their interest and adopting natural history as a pastime.

In the first half of the 19th century, working-class naturalists with jobs in industry found relief from their tedious indoor occupations by exploring

the countryside around their homes. This urge for natural history was confined to artisans from industrial habitats. For those who laboured on the land, nature already filled quite large enough a part of their lives – just as few farmers or farm-labourers today take any active interest in natural history.

Unable to afford a horse, much less a carriage too, industrial working-class naturalists explored limited tracts of country around their homes very thoroughly on foot. This style of natural history stood in marked contrast to that of more affluent middle and upper class naturalists of the time. The Industrial Revolution had created much wider geographical and intellectual horizons for travellers interested in geology and natural history by enabling them to explore further more frequently, satisfying their desire for evermore varied experiences and perceptions. Those who could afford assisted transport to ferry them further afield were additionally fortunate not to be constrained by the lower-class's long working hours, so their excursions could extend further in time as well as distance. In consequence, middle and upper class natural history was much more wide-ranging than that of artisans, both geographically and in subject-matter. A well-to-do naturalist might collect and compare plants and animals from all over Britain, as well as overseas.

But there was a drawback to this more affluent style of natural history which was to have an unfortunate and persistent subsequent effect, for whereas working-class naturalists repeatedly searched the same localities at different times of the year, more peripatetic naturalists typically visited a locality only once or twice, so the results of their searches showed seasonal bias. One might therefore expect artisan naturalists to have elucidated the life-cycles of species more thoroughly than middle and upper class naturalists. But if they did so, their findings were not recorded and have not survived. As with the recording and subsequent interpretation of other aspects of natural history, few discoveries in natural history by illiterate lower-class people have survived to inform posterity. Parish priests, on the other hand, ideally bridged the gap between the illiterate, parochial world of artisan naturalists and the literate, wider world of the bourgeoisie and gentry, being both literate and relatively leisured, but at the same time shackled to their parishes. So of all naturalists in the 19th century, priests were those most likely to elucidate and record seasonal variations of species' growth and activity.

Unlike natural history, biology did not interest the upper classes because its study conferred no social esteem, while the lower classes took no interest in biology because their poverty and illiteracy largely barred them from investigating links between organic cause and effect. Instead, biology interested only literate members of the middle class who envisaged distant commercial prospects ultimately enabling them to adopt leisured, gentrified life-styles proclaiming that they too no longer needed to worry about the vicissitudes of nature or economic exigencies.

With the science behind more industrial middle-class occupations presenting new intellectual challenges to the long-standing socio-economic superiority of the land-owning class, the aristocracy sought to consolidate their advantages and corporate identity with the Enclosures Acts, and retreated behind hedges and fences, a move designed to preserve their intellectual as well as territorial identity. But their intellectual insularity soon became isolation. The Anglican-Tory hierarchy derived from the 'county set' saw little attraction in esoteric studies of fine organic detail. The *nouveauroche* middle class was welcome to occupations of such dubious social esteem, an attitude which continued to poison British interest in science throughout the 20th century. Thus, there was a sectarian as well as an intellectual divide between *alfresco* natural history supported by Anglican clergy and other pillars of society, and the new laboratory-based professional biology which attracted the upwardly mobile sons of industrial toil who were sympathetic to dissenting religious creeds and political doctrine (Desmond, 1989).

Liberal social policies originating from continental Europe after the Napoleonic Wars fanned the flames of social discontent and sectarian antagonism. Members of the upper class had inherited their wealth and influence and regarded the world as created by an almighty power who maintained order in Nature and the status quo in Society. In contrast, the lower classes worked for material gain, and found ideological justification for economic policies facilitating social reform in the new biological theories of organic development.

In the middle years of the 19th century, as biology became the intellectual darling of the middle class – particularly for those members living in industrialized environments – affluent amateur naturalists continued their hunt for species to catalogue, an occupation already tinged with nos-

talgia for a bygone era when such pursuits had still represented the leading investigative edge of field-science in pre-industrial Arcadia. Biological theories, on the other hand, such as those of evolution, were largely products of minds from competitive, *laissez-faire*, industrialized communities where effort stood a chance of material reward. This intellectual arena was a far cry from the landed gentry's world of inherited privilege, where species were as immutable as the God-given status quo.

Comparative anatomy, embryology, and the concept of evolution were imported from France, and enthusiastically adopted and endorsed by the Dissenting classes as ideological justification for their own political agenda and socio-economic advancement. These biological sciences, and the horrors of organic alchemy promulgated as theories of evolution, describing how and proposing why living forms change with the passing of time, appalled the upper, Anglican, Tory class, which saw these notions as threats to their inherited privileges and influence. The ruling class felt more comfortable with an unchanging world ruled by celestial force rather than self-determination, with compliant lower classes genuflecting to higher earthly and heavenly authorities instead of being diverted by radical notions of organic development, social change and self-advancement.

While microscopes endowed social status in the drawing room, their fuller applications in exploring nature were acquiring professional connotations. Elite, salaried, 'closet' naturalists held the top scientific posts, dominated the indoor arena of learned societies and journals, and the laboratory, where microscopes had become *avant-garde* tools of research, thus carrying the leading investigative edge of biology far beyond the sphere of amateur interest and polite society. For whereas naturalists used microscopes to find and describe diminutive species, the recent technological advances in microscopy enabled biologists to use them for investigating more closely and analysing more accurately fine details of the structure of tissues which lay beneath the external surfaces of organisms, large and small alike.

As slides of sectioned and stained tissues began to find their place alongside cabinets of dried plants and stuffed or pickled animals, these developments in microscopy brought to light increasingly convincing connections between form and function – between organic cause and effect – in the development of individual organisms, opening up the new sciences of embryology, and later histology and cytology alongside evermore soph-

isticated studies in comparative anatomy. As biologists began to better appreciate the link between form and function, they found fresh and more persuasive answers to the old question 'Why does that organism look like and perform as it does?'

But there was a price to pay for this gain. The compartmentalization of microscopical studies severed the hitherto seamless unity between natural science and natural history. Where the newly institutionalized science of biology was from its inception laboratory-based, professional, and esoteric in text and technique, natural history remained amateur, *alfresco*, and descriptive, shunning the search for cause to explain diverse effects. The microscope, increasingly associated with the indoor arena of the newly professionalized science of biology, generated an aura of esoteric exclusiveness which, combined with the daunting diversity of invertebrate and cryptogamic species, doubtless deterred most amateur naturalists from close interest in these diminutive species. The amateur felt more comfortable out of doors searching for larger animals and plants which formed so prominent a part of the familiar countryside. Thus, the schism between natural history and professional biology in the first half of the 19th century not only mirrored the social classes of their respective disciples, but became an intellectual schism as well.

Studying microscopic species proved of little allure to many naturalists, for the insurmountable lapse of time between enjoyable discovery in the field and certain identification by microscope in the drawing room has always stood between a majority of naturalists and familiarity with such diminutive quarry. For those naturalists less entranced than they might have been by the recondite wonders of microscopic life, and with the flow of undescribed vertebrates and vascular plants slowing to an unsatisfactory trickle, the demand for suitable new subjects to study in the second quarter of the 19th century prompted some naturalists to resume the tradition of searching overseas for new species of vertebrates and vascular plants. The fruits of the Industrial Revolution had increased the ease and reduced the expense of travel, and as continental Europe became safer again once the Napoleonic Wars ended and European nations sought to consolidate their empires overseas, naturalists could once more contemplate the prospect of discovering species abroad. But these naturalists were in a minority – either wealthy explorers with insatiable wanderlust, or poorer journeymen such

as John MacGillivray and T.H. Huxley aboard naval vessels charting the globe, who had to earn a living and reputation from selling or writing up the specimens they brought home. Only a minority of naturalists were able and inclined to bear the costs, risk the dangers, and suffer the discomforts of travel overseas.

Another handful of naturalists occupied themselves by elucidating the life-cycles of conspicuous animals and plants already known to science. But many naturalists in the second quarter of the 19th century found the new challenge they were looking for by adopting an altogether different manner of studying nature – one which heralded much more far-reaching consequences for how most naturalists were to occupy themselves in the decades to follow than trawling for new species down the microscope, elucidating life-cycles, or venturing on the naturalist's equivalent of the Grand Tour. These new naturalists preferred to study familiar species of vertebrates and vascular plants in the field in new ways. They knew what these species were, and how to recognize them, so they began to study when and particularly where such species could be found. As the greater volume of traffic and extent of travelling increased awareness that different species not only lived in different habitats but also had different geographical distributions, the bulk of attention in British natural history shifted from looking for new species in familiar places to looking for familiar species in new places, in order to elucidate their geographical distributions and haunts. In Britain during the second half of the 19th century, H.C. Watson's vice-county network became a cornerstone of this new interest in studying species' distributions.

The old style of describing freshly discovered species and their preparation for the cabinet or herbarium had been a mainly indoor occupation. But the new naturalists (many of them clergymen residing in country parishes where they dovetailed their professional commitments with close and often life-long studies of local natural history) were interested in species' haunts and geographical distributions, and studied living organisms in their natural environments as well as their dried remains in the drawing room. Old-style natural history societies had sought only to enshrine the preserved remains of extinct and extant species in museums, but by the middle years of the 19th century they began to find themselves rubbing shoulders with the new field clubs springing up all over England, whose

interests embraced not only the lifeless forms but also the vital performances of species.

Moreover, from about 1850 onwards, the spreading network of railways in England enabled parties of naturalists to travel considerable distances quickly in comfort and safety, further encouraging the activities of field clubs, which largely superseded the literary and philosophical societies whose natural habitat had been the debating chamber (Allen, 1976). Thus, much of the interest previously directed at the predominantly indoor pursuits of describing and classifying large animals and plants shifted out of doors towards investigating how and where they lived.

Field clubs were always to remain a mainly English rather than British phenomenon, for the network of railways developed far more in the flatter, more populous English counties than in the more sparsely populated and topographically difficult highland areas of Britain. Furthermore, the fullest development of the Victorian network of local railway-lines more or less traced the extent of influence of the Anglican Church, a sect which never won influence in Welsh, Scottish or Irish communities, and was institutional home to the peculiarly English notion that natural history was a more suitable pursuit for the leisured classes than for those unfortunates who had to go out to earn a living each day.

While naturalists continued their search for new species, or for differences in life-cycles or geographical distributions, scientists became pre-occupied in the second quarter of the 19th century with Cartesian classifications of natural phenomena. Although naturalists of the 18th and early 19th centuries (such as Cuvier with fossils, and Lamarck with evolution) had indeed perceived a connection between Nature's past and present, it fell to a subsequent generation reared in a society increasingly influenced by swift socio-economic change in the 19th century – most notably Lyell (1830–1833) in geology and Darwin (1859) in biology – to forge convincing links between Nature's present forms and their past histories, compelling natural history's classifications of spatial form to make room for classifications of temporal events as cause and effect. In doing so, natural history had given birth to geology and biology. But scientists were unable to calculate the ages of rocks and fossils until the middle of the 19th century, so only then did it become possible to construct a persuasive account of how and when species had changed, and challenge celestial

authority with terrestrial explanations of organic and inorganic diversity. Before 1859 biologists had seen little convincing connection between the present state of the living world and its origin and development in the past. But from the mid-19th century onwards, the geological and biological disciplines spawned from the theories of Lyell and Darwin consigned natural history to the role of a distant and passive spectator as natural sciences developed intellectual agendas which were completely divorced from the descriptive classifications of natural history.

By the late 18th and early 19th centuries so many species – and so many differences between those species – had come to notice that this bewildering diversity of organic form and development was becoming unmanageable. No longer could anyone hope to acquire familiarity with every species, so a need arose to restore order by introducing hierarchical classifications of organic forms, in which species were grouped according to their similarities and shared features. These hierarchical classifications of like with like became genealogical as well, for they implied a shared organic origin: that organisms which are now similar but nevertheless differ consistently had once upon a time looked identical, and must therefore have since evolved from a shared ancestral stock.

In the late 18th century, naturalists began constructing hierarchical classifications of species by comparing various of their features. Species which were most similar to each other were grouped in one genus; similar genera were grouped in one family; similar families in one order; orders in classes, and classes in phyla. This comparative approach stood in contrast to that of Linnaeus only a generation earlier, who had sought a method for reliably identifying species – mainly vertebrates and vascular plants. In the main, these organisms identify others of their kind by their sexual or sexually associated features, so Linnaeus had been right to distinguish them by their sexual or sexually associated features.

But whereas naturalists such as Linnaeus classified species because they wanted to distinguish them, Lamarck and Geoffroy and other comparative anatomists wanted to do the opposite. They wanted to compare species – to classify them according to features they share. They therefore took account of a greater range of organisms' features than Linnaeus had, and considered internal anatomical attributes as well as externally visible sexual and other features.

Although the original purpose of hierarchical classifications had been to bring order to an ever-increasing diversity of described species which had threatened to overwhelm naturalists' efforts to assimilate them, another but initially unforeseen advantage subsequently became apparent. Hierarchical classifications based on a sufficiently wide variety of organisms' features also traced species' putative evolutionary origins and affinities, developing an older notion that all organisms were members of a 'great chain of being'. The new hierarchical classifications caused naturalists to wonder if some species had changed into others. Species in the same genus were thought of as sharing one evolutionary ancestral species; those in the same family had an earlier, more remote ancestor, and so on. Thus, those hierarchical classifications based on a sufficient variety of organisms' features are supposed to trace evolutionary descents from increasingly remote common ancestors.

The new intellectual outlook which emerged after the clash between Cuvier and Geoffroy St Hilaire – a conviction that patterns existed in nature and that unifying causes therefore underlay nature's bewildering complexities – found its purest expression in the minds of Lyell and Darwin. Their interest in causes marked them out as scientists, even though both had grown to manhood as naturalists.

While contemporary minds continued to celebrate a celestial cause of earthly natural effects by contentedly cataloguing the consequences of Creation, those of Lyell and Darwin jumped out of gear from the endless sequence of environmental events, forming mental worlds which were no longer merely reactions to the surrounding climate of ideas, but reversed the inexorable passage of time in the environmental world by invoking causes observable today in order to explain effects which occurred in the distant past. Lyell established that weathering and erosion, sedimentation, and movements of the Earth's crust had continually been altering the shape of the Earth's surface. Indeed, the very subtitle of his *Principles of Geology* was 'an attempt to explain the former changes of the earth's surface, by reference to causes now in operation'. Similarly, Darwin showed that the same ecological forces which drive natural selection today have moulded the evolution of species since life began. His ecological theory of natural selection proposed that the competitive struggle to survive and thrive, causing natural death-selection evident in contemporary nature,

had always influenced the development of organisms' material forms and energetic performances: an extant ecological cause of evolutionary extinctions in the past. Thus, both men postulated enduring, observable, inorganic geological and organic biological causes which had created bygone landscapes and species, and indeed were still creating new ones.

These radical general theories which overturned and dispensed with long-cherished assumptions and constituted an intellectual revolution in geology and biology were products not only of ideas inchoate at the time, but also of the cultural conditions in which Lyell and Darwin spent their formative years. The potential for generating such radical ideas was confined to affluent members of a middle class who reached maturity during the 1820s and 1830s in western Europe, and they appeared and thrived as a consequence of the socio-economically rare combination of austerity and opportunities between the 1790s and 1820s. Recession and the Napoleonic Wars generated austerity which brought a competitive edge to the cultural climate, while the Industrial economic and French social Revolutions created incentives and opportunities for financial profit from entirely new life-styles and states of mind. This combination of stick and carrot fired the imagination and stiffened the resolve of a generation of minds, bringing them to very productive maturity in western Europe at the end of the first quarter of the 19th century.

Not only were Lyell and Darwin brought up at a time so potentially rewarding for advancing contemporary scientific ideas in public, but both men were born into an affluent middle-class social stratum in which the ethic of effort and work was encouraged. Yet neither man had to earn a living by pressing his nose to a professional grindstone. This fortunate combination of effort and affluence enabled Lyell and Darwin to disdain an Anglican education which found truth and good taste on the pages of Greek and Latin texts. After toying unenthusiastically with their studies at university, into which science did not intrude, and flirting with the orthodox theories circulating in these bastions of classical tradition, Lyell and Darwin both withdrew to private, sequestered enclaves where they became immune to the numbing conformism of academia, and could study nature heuristically, free of censure, pursuing their ideas according to personal fancy on their private intellectual and topographical odysseys. This unchaperoned development of ideas is precisely (indeed, the only)

circumstance in which seminal ideas can form... 'Nine times out of ten... [a] great improvement in a field of endeavour is obtained by the intrusion of [images and idioms,] methods and notions that were not foreseen within it.' (Valéry, 1895). Consequently, it is hopeless to expect institutionalized minds of latterday professional scientists to conceive innovative theories with a breadth of imaginative vision comparable to those of Lyell and Darwin before the age of specialization.

Darwin's upbringing and early interests were in natural history, but he came to think more like a biologist than a natural historian as he searched for pattern in the past and a common cause of the diversity of species, postulating an evolutionary ancestor shared by similar extant species. His theory of natural selection distinguished ecological cause from evolutionary effect, a propensity which set him apart from the descriptive proclivities of natural historians. Indeed, though Darwin's theory catapulted biology into an era of rapid and far-reaching development, spawning many biological theories and disciplines, it affected the interests and activities of natural historians but slightly. Darwinian theory was the province of a new breed of professional biologists, rather than the parish priests who so dominated the English army of practising field-naturalists.

Old-time naturalists such as Buffon, Lamarck, and Erasmus and Charles Darwin were all-rounders. Not only could they identify a wide variety of animals and plants, they also wanted to know them by their habits and habitats, life-cycles and life-styles. In consequence their theories regarding diversity in organic and inorganic nature became esemplastic explanations of variety in life and landscape – unifying in their mind's eye an apparently endless variety in the environments surrounding them.

But the world of the all-rounder was passing into history by the middle of the 19th century, for just as each man kills the thing he loves, every state of mind creates a new condition in which the former can no longer thrive. 'The intellectual world as well as the physical world has its generations', wrote Bonnet, and theories change down the years, with long periods of specialization interrupted by brief interludes of iconoclastic generalization. In natural science the pendulum swung from general ideas and eclectic interests in the 18th and early 19th centuries to extreme specialization by the late 20th century. Contemporary scientists still look for general biological theories, but their quest has foundered with the relentless

proliferation of disciplines and fragmentation of theories since the mid-19th century.

Lyell and Darwin were swansongsters for the age of polymathy, whose apogee had arrived in the late 18th and early 19th centuries. As young men in the 1820s, they belonged to the last generation of gentlemen with independent means who ranged at will through fields of enquiry subsequently reserved for professional scientists with paymasters to satisfy. In those days a gentleman could still chart geological strata afresh and find conspicuous animals and plants not previously known to science as he strolled the umbered hills and smooth green miles of turf. Murchison, for instance, catapulted in a remarkably short time from the front line in the Napoleonic Wars to the forefront of geological research – an entirely new endeavour for him – in which his military eye, practised in identifying structural features of landscapes would have preadapted him for his subsequent cartographic career. Otherwise, though, his first career little prepared him for his second.

The first half of the 19th century saw an end to such boundless exploration of and speculation about Nature's mysteries. Just as the Enclosures Acts had parcelled off much of the British countryside, knowledge too was becoming compartmentalized. As years rolled by, the landscape of biological ideas became increasingly populated with more and more disciplines. It became ever more difficult to study nature regardless of rules for how to do so. Free spirits were no longer welcome to roam at will through fields of enquiry hedged off and jealously patrolled by scientific priesthoods which enjoyed power over and privileged access to their professional domains as exclusive as those previously appropriated by men of the cloth. In a God-fearing Victorian age, disparity between the observable behaviour of the world and religious propaganda purporting to explain its origin and present state had once provoked the formation of general theories of nature to supersede omniscient supernatural authority. But by the second half of the 19th century, the general theories of all-rounders had in turn created new intellectual conditions in which specialists thrived, with distinct new subjects centred on various stages of the general theories' concatenations. In biology, for example, where anatomy once held exclusive sway, Darwin's theory of evolution by natural selection linked an ecological cause (natural selection) with a myriad of evolutionary effects – of why organisms look like and live as and where they do, what

they consume, how they digest, breed, and compete with others. All these questions demanded answers from the rapidly developing disciplines of physiology, biochemistry, embryology, and the new subjects of genetics and ecology. All-rounders were neither required nor welcome in these specialized sciences, and lost their place in the pantheon of scientific stardom. The days had gone when a gentleman might arrive at the frontiers of scientific knowledge by indulging himself with a little reading, collecting, and a few evenings at the microscope.

Even though all corners of literate society in the second half of the 19th century discussed Darwin's new theory of evolution by natural selection, his ideas prompted few fresh developments in the study of nature in the field. By 1859 naturalists had already begun the field-study of species' habits, haunts, and geographical distributions. Of animals, the larger invertebrates – insects, crustaceans, molluscs, etc. – were among the most popular subjects for amateur study, being approachable as well as reasonably conspicuous, and not requiring use of expensive equipment. Not only were many such species described new to science during the second half of the 19th century, both near to home and abroad, but the life-cycles of many already familiar species were also elucidated.

Meanwhile in botany, although European cryptogams new to science made their taxonomic débuts at frequent intervals, much of the European vascular flora had already been described. So by the 1860s, leading botanists had for many years been studying 'difficult' groups of plants which failed to display well accentuated distinctions. Plants such as brambles and hawkweeds, which reproduce asexually, possessed a daunting array of subtle differences, as did those which hybridize, like roses, willows, and willow-herbs. In contrast to sexually orthodox plants which united only with other members of their species and set seed in the approved Christian manner, the perverted reproductive proclivities of brambles, willows, etc., precluded easy elucidation of these species. Darwin's proposal that hardly any two individuals within a population are the same, and that innumerable differences occur between individual organisms of a species which may breed true certainly encouraged botanists to look more closely at asexual clones and hybrid swarms, and alerted all naturalists to the variations occurring both within and between populations of similar organisms.

Even so, the theory of evolution by natural selection was neither a cause nor a consequence of this interest, or of the abandonment of the closet for the field. Rather, it articulated Nature's equivalent of the cut-throat free enterprise of contemporary industrial society, and particularly the competitive superiority of the middle class to which Darwin and other proponents of evolution themselves belonged – a far cry from the divinely justified status quo of a vanishing ecclesiastic culture. Like the naturalists' move into the field, Darwin's new theory of evolution was as much a quest to confirm how organisms compete and live together as an outcome of the increasingly glaring inconsistencies between Biblical dogma and the accumulating geological and biological evidence.

Darwin's theory of evolution by natural selection offered a new explanation for why organisms have changed in the course of time, and will continue to do so. Evolution by natural selection shouldered God out of the reckoning as a cause of organic diversity, and destroyed the happy marriage between God in Heaven and Nature on Earth, divorcing natural history from its role of interpreting the diversity of life and depriving it of the momentum necessary for its further development. Naturalists continued to avidly collect and catalogue species into the 20th century, but as evolutionary theory gradually took hold of contemporary popular culture, it eroded the arrogant certainty that God had created each species. Naturalists could no longer presume to interpret or explain the variety of species, as they had before 1859. Professional biology filled the conceptual space vacated by God, and the advent of genetics and ecology in the 20th century finally overwhelmed what little scientific status natural history still retained. By then theory and experiment were needed to interpret the relationships between organisms, and between organisms and their environment. The science of biology irrevocably shattered natural history's serene tryst with God as the fount of organic diversity by replacing Him with ecological and genetic causes of anatomical and metabolic effects.

The zeal which had driven natural historians to find and describe God's bountiful creations passed to biologists, who undertook to investigate and explain the causes underlying the forms and activities of organisms. Natural history therefore carried on during the second half of the 19th century very much as it had before Darwin published the *Origin of Species* in 1859. As soon as his evolutionary theory offered natural

historians a glimpse of the history of nature, they surrendered interest in and practical investigation of that history to geological and biological science. Having sacrificed God in order to accommodate evolution as the new fount of organic diversity, natural history shunned the new discoveries in and theories of comparative anatomy, embryology and physiology, and later treated genetics and ecology likewise. Natural history therefore found itself cast adrift from the surging developments in biology and geology, trapped in a time-warp since the mid-point of the 19th century. Naturalists today continue to explore and describe, but the start of the 21st century finds them studying nature in ways and towards ends remarkably similar to those of their Victorian predecessors. Amateur field-botanists, for example, remain as preoccupied with documenting the geographical distributions of species as H.C. Watson was before 1850.

### 3. NATURAL HISTORY IN THE 20TH CENTURY

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THE CLOSING DECADES of the 19th century saw an increasingly single-minded surge towards investigating the internal physiological and anatomical affairs of organisms, as the spiritual descendants of closet-naturalists in the early 19th century donned white coats, moved their microscopes from the drawing room to the laboratory, and stayed indoors. Their laboratory-based occupations allowed no time for and admitted no interest in the study of whole organisms in their natural surroundings. Consequently, while Darwin's theory of evolution greatly influenced biological theories, his ecological theory of natural selection became of as little importance to physiologists, biochemists, embryologists and their ilk in the laboratory as it was to amateur naturalists in the field. This move by professional biology away from field-studies delayed the development of ecology until the beginning of the 20th century – fully half a century after Darwin had articulated its most fundamental theory.

Links between old-style natural history in the field and the new biological disciplines became evermore tenuous as the 19th century gave way to the 20th. But they were not entirely severed, for the older generation of university scientists remained dyed-in-the-wool naturalists, turning out at

the field clubs' excursions when their professional commitments permitted. Doubtless, on these occasions, they imbued the more receptive amateur stalwarts of the field with an understanding of professional science's attitudes and theories. However, almost as soon as ecology began to assume independent form as a recognizable biological discipline, the advent of the First World War overthrew the lay public's prosperity and leisure, and hence also their interest in natural history.

The period between the World Wars saw birdwatching – by then far and away the most popular branch of British natural history, as binoculars and telescopes became generally available, just as microscopes had a century earlier – harnessed to the new science of animal ecology because (and only because) each shared an enthusiasm for counting numbers of individual birds in delimited areas. But this was no meeting of minds between amateur ornithologists and professional ecologists, rather a marriage of convenience, and one suitable only for ornithology. The promise of a durable and productive collaboration between professional and amateur ornithology merely flattered to deceive. In any case, economic and social conditions during and between the two World Wars became too austere for the British bourgeoisie to sustain or foster their interest in natural history.

With the First World War diverting the public's attention from natural history, professional botanists (and later also zoologists) encountered no public resistance as they appropriated ecology as a biological discipline, which therefore ceased to be a legitimate domain for amateur natural historians. Thus natural history surrendered to professional science responsibility for investigating cause and effect in the countryside, just as it had yielded the indoor arena in the previous century. Moreover, by the time of the Depression in the 1920s and 1930s, the professional classes found themselves no longer 'paid to work' but working to be paid. For example, the disappearance of clergymen from the ranks of amateur field-naturalists between the World Wars was a direct consequence of a precipitous drop in their standard of living. People had more pressing concerns than a leisurely investigation of the beauties of nature.

Only with the economic boom after the Second World War did the public's leisure-time wax once more, along with their disposable incomes, rekindling their interest in natural history. But by then the domains of

ecology, genetics, and evolution were safely out of bounds to the amateur, protected from public intrusion by esoteric theories and impenetrable prose. Just as the escalating numbers of species coming to notice in the 19th century had deterred naturalists from trying to become familiar with them all, so in the 20th century a proliferation of dauntingly esoteric theories, techniques and languages in physiology, cytology, embryology, genetics, ecology, evolution, etc. deterred natural historians from taking close interest in how and why organisms look and perform as they do. Frightened and frustrated by scientific language, amateur naturalists found in the second half of the 20th century that they had long since forfeited to professional biology their legitimate interest in the history and present behaviour of nature. Amateurs were no longer free to blaze new trails through intellectual territory now reserved for professional contemplation, and subjects of enquiry traditionally pursued by naturalists ceased to be common ground over which lay people might disport.

Natural history remained an amateur middle-class pursuit, but the cost of living continued to rise remorselessly, and professional men had to work harder for longer hours and less pro rata reward. Many naturalists could therefore only take up natural history in earnest after retiring on pensions sufficient to buffer them from the exigencies of life during their tranquil years, while enjoying health and mobility (with motorized help) further into their dotage than had been possible in previous generations. The loss of domestic staff at home also left fewer uninterrupted leisure hours during child-rearing years, so whereas well-to-do Victorian naturalists found plenty of time for natural history early in adulthood, with correspondingly high levels of energy on tap for pursuing their interests, many of their Elizabethan successors have had to wait until the second half of adulthood before taking up natural history in earnest. As the age-profiles of natural history clubs rose accordingly, their members could only accommodate more languid excursions and rates of study, in deference to their waning levels of disposable energy.

In consequence, in the 20th century, many of those coming to field studies in earnest for the first time, although as enthusiastic as their Victorian predecessors, were neither as energetic nor as likely to embrace seminal new ideas, or embark on innovative investigative field-work. Minds which have passed through their intellectual menopause are notoriously

reluctant to embrace novel ideas or techniques, so it comes as little surprise that post-war natural history has shied away from incorporating ecological theory into practical field-studies.

The 20th century was therefore a lost era for natural history. Neutered by its divorce from laboratory science and biological field-studies, the start of the 21st century finds natural historians still shy of ecological questions formed and then abandoned at infancy by a generation of Edwardians whose attention had been so brutally diverted from the beauties of nature to the bestialities of war.

Natural history begat ecology at the start of the 20th century, a development which promised so much for natural history, yet has delivered so little, and 100 years later ecology shows little sign of encouraging amateur naturalists to enquire into why animals and plants live where and as they do. Moreover, with increasingly fierce cuts in public expenditure, field-courses have priced themselves out of many degree-courses, and likewise field-studies out of contention for the hearts and minds of grant-dependent career-biologists who have to produce applied dividends. Weakened by its failure to escape the second-class status of a descriptive exercise and develop into a predictive science, ecology succumbed to ruthless financial pruning in the late 20th century, and all the glamour of ground-breaking biological research has continued to be in the laboratory rather than the field.

Horrified by wholesale destruction of life and habitat in the Second World War, long since deprived by Darwin of a supernatural explanation for the origin of species, and deterred by esoteric scientific language from familiarity with the earth-bound causes of their forms and performances, from the mid-20th century naturalists turned for consolation to a new religion. This was the far less intellectually challenging future of nature – conservation – an interest dripping with moral righteousness, riddled with rectitude, very far removed from the spiritual conception of natural history, not even requiring familiarity with and skill in identifying species, much less an understanding of their evolutionary genetics and ecological occupations. Well-informed conservation demands knowledge of the specific identities of animals and plants across the spectrum of organic diversity, and of their life-cycles, genetic repertoires, metabolic abilities and ecological performances. But much of the literature of conservation is a pros-

elytizing effluent of opinionated ignorance. Whereas Victorian naturalists carefully identified species when they studied living nature, many latterday conservationists prefer to garden the wild according to high-principled dogma rather than with a familiarity of diverse species. The moral fervour with which priests and other pillars of Victorian society flocked to the field clubs in order to marvel at The Almighty's wonderfully diverse creations finds contemporary expression in conservation and membership of 'wildlife trusts', as popular now as the field clubs were in the 19th century.

One benefit of natural history's expulsion from mainstream biology has been its escape from the stultifying influence of educational syllabuses since early in the 20th century. Natural history has long since departed the classroom and medical school, scorned as an educational irrelevance, superseded by biology as the educationally correct way to study organisms, be they alive or dead, captive or free. Sadly, the microscope has become a powerful symbol of mandatory instruction in the science syllabus, rather than a means of independent entertainment in the evenings at home, where latterday naturalists find themselves beguiled by more passive forms of entertainment. Meanwhile in schools, teachers no longer instruct pupils which species to study, or how to identify them. Free of rules and regulations, far removed from educational demands, economic cares and social mores, natural history (shorn of its bastard child, conservation) happily remains one of the very few domains of modern life devoid of any malodorous moral dimension. The very charm of natural history derives from its amateur status, studied not for material gain, but out of independent curiosity and for individual pleasure alone.

## 4. BIOLOGY IN THE 20TH CENTURY

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CAUSAL LINKS between anatomical form and biological function became increasingly convincing in the second quarter of the 19th century, as microscopy revealed the wonders of fine detail and internal organization in tissues. As the century wore on, the rise of embryology, biochemistry, physiology and other disciplines made biologists and naturalists realize that not only did organisms' sexual selection of breeding partners determine the visible features of their offspring (as farmers, gardeners, pigeon-fanciers, dog-breeders, etc. had known for a long while), but also that these inherited features in turn influenced metabolic ability, behaviour, dietary requirements, strategies of hunting and preference of haunts.

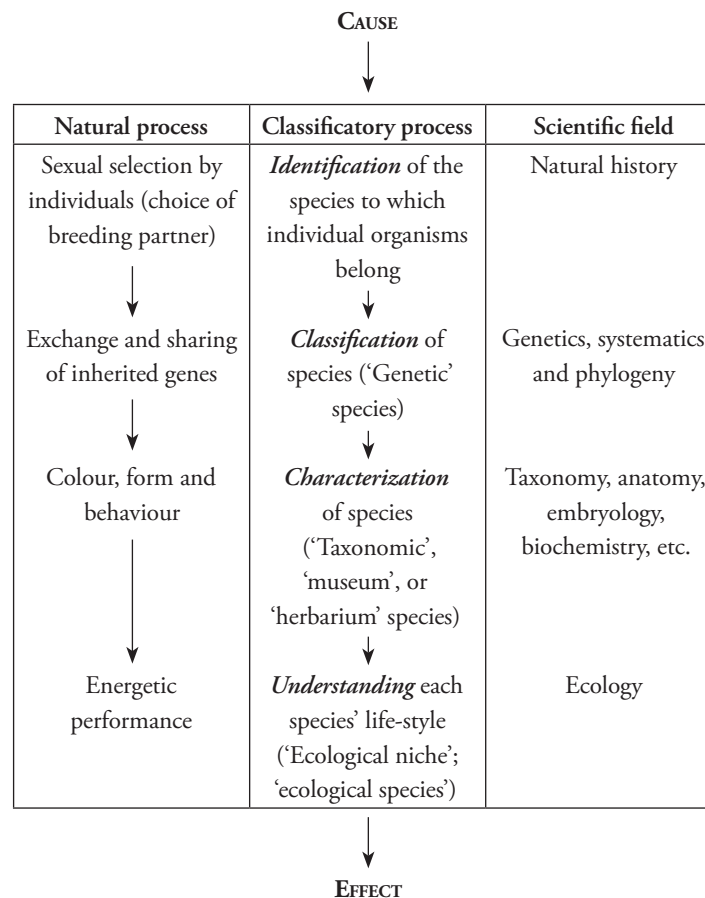
The rise of genetics and ecology early in the 20th century completed an organic concatenation which continues to constitute the spine of contemporary biological theory. When biologists realized that the nuclear material which they could now see contained the genetic information organisms inherited from their parents, a hitherto abstract concept assumed visible form and promised to reveal how parents bequeathed heritable characteristics to offspring.

A few decades later, as biology in the mid-20th century forsook the microscope for the electron microscope, probing from cellular to molecular levels of magnification, it became apparent that genetic information is represented by the identities and linear arrangement of nucleic acids, or genetic letters, and that as organisms grow and develop they translate their inherited genetic instructions into proteins, which in turn determine their physiques and metabolic abilities. Just as the combinations and order of spoken and written letters and words determine their meanings, the identities and linear arrangements of genetic letters and words determine the identities of proteinous letters, or amino acids, and hence the molecular shapes of the proteins they constitute. The conformations of proteins in turn determine their functions in the body, and ultimately an organism's physical looks, metabolic performance, and ecological livelihood.

Organisms which differ genetically not only look different but also behave and live differently. Each species, being genetically distinct, differs in its metabolism as well as anatomy, and therefore performs in characteristic ways, influencing for example what food it can catch and consume, and which constituents it needs in that food. The anatomical attributes and metabolic repertoire of a species therefore determine the unique range of conditions in which it can survive and thrive and exploit sources of energy in ways which no other species can match, either by the kind of life they lead or the efficiency with which they can perform the same tasks in the same circumstances.

Thus, choosing the right sexual partner is crucially important for the well-being of an individual organism's offspring because the particular mixture of genes which offspring inherit from their parents determines their own genetic constitutions, and hence bodily conformation and looks, metabolic abilities, and ecological performance. The faithful connection between the identities of inherited genes and an organism's physique and behaviour is the reason why offspring closely resemble their parents, and why all individuals in a breeding population (or species) resemble each other, while differing from organisms of other species with which they cannot exchange genetic information by interbreeding. From John Ray (1686) to the present day, the concept of the species (an assemblage of organisms sharing continuously variable features which are distinct from those of other organisms because it does not interbreed with them and so

exchange and share genes) has rested on the notion that like breeds only with like, by which means we now know that they exchange and share heritable characteristics.



All sexual organisms enact this organic odyssey from choice of breeding partner to ecological success as they pass through their lives. Biologists recognize and distinguish species most reliably and classify organisms' evolutionary affinities most successfully when they follow the same sequence that organisms do in the course of their lives – identifying organisms by

the same sexual features that the organisms use, then classifying them using genetic information (which summarizes their inherited features and evolutionary affinities), characterizing them using conspicuous features of form and colour, and understanding them ecologically in terms of how, where, and when they make their livings. Naturalists and biologists alike find it satisfying when genetic or biochemical or ecological studies confirm the delimitation of species long recognized on grounds of colour and form, fascinating when they indicate the existence of hitherto unrecognized species, and instructive when they show that features of physique had been used inappropriately to delimit species.

We have become comfortable with the notion that choice of breeding partner influences the inherited traits of offspring, and that these features of form and function in turn affect how organisms live, where they thrive best, and when they are most active. Yet neither biologists nor naturalists think of species in terms of their various anatomical, genetic, metabolic and ecological features. Only systematists (biologists primarily concerned with classifying organisms) think in general terms of 'biological' species, being neither encumbered by the specialized equipment and experimental techniques of the laboratory scientist, nor preoccupied (like field-biologists) by the complexities of organisms' environments, while naturalists have drifted to the margins of contemporary taxonomy and developmental anatomy. Indeed, orthodox though the organic concatenation from sex to success has become, it remains to be substantiated for most species. Only in a minority of instances have genetic differences or preferences for particular habitats been shown to correspond to interspecific differences in features of form and metabolism.

Through familiarity with the genetics, systematics and ecology of species we can understand their evolutionary and genetic histories, material appearances, energetic performances and ecological occupations. These link each individual organism's present self, the past in which it retains its essence, and the future in which we feel encouraged to search for it again. But we lack a popular biology, a contemporary equivalent of natural history in yesteryear, conceived as a general biological theory, communicated in exoteric language, attractive to, discussed between and studied by people from all walks of life. A theory of why organisms look like and live as they do would bring coherence to the modern science of life,

restoring continuity between the organic world's evolutionary past (which determines its present form) and its ecological performance (which will determine its future prospects) – a continuity which Darwin laboured so assiduously to establish, but relentlessly eroded by 150 years of subsequent specialization.

Satisfying though molecular biology can be in describing how organisms work, it offers no explanation of why they look like and live as they do. Similarly, the link between sex and success describes how organisms live, but fails to explain why living forms and events appear as and when they do precisely because it so faithfully recounts the order in which they occur. In the same way, theories of the origin of species offer explanations of how species arise, but do not explain why evolution occurs and are therefore only of ephemeral evolutionary interest. Molecular genetic changes solve organisms' ecological and evolutionary problems, but they are not criteria of success and therefore do not solve the problems of biological theory. Confronted with these, 20th century biology either resorted to tautology or fell silent.

## 5. BIOLOGY IN THE 21ST CENTURY

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MOST MEDICAL and agricultural benefits of biological research in the 20th century came from laboratory-based biochemical, genetic and immunological research into how animals and plants work internally, rather than from the commercially unrewarding studies of how they live in their natural environments. Field-studies therefore look set to remain the Cinderella of life-sciences in the 21st century, while molecular biological research will continue to attract more funding and pay bigger dividends.

Nevertheless, biologists continue to seek esemplastic explanations for organic diversity by studying similarities between organisms, between species, and between the communities they form. These similarities interest biologists because they reveal patterns and trends in organic development, and offer the prospect of formulating a general theory of organic performance to explain the growth of organisms, evolution of species, and succession of natural communities and human civilizations. The quest for this general theory of organic development lies at the far end of the intellectual spectrum from lavishly funded technological investigations of how organisms work internally.

Leonardo da Vinci (c. 1500) remarked that although nature proceeds from cause to effect, we must do the opposite, namely, begin with our experiences and investigate their causes. In fact, there are two kinds of theory and explanation. The first kind – Leonardo's – enables us to reflect on the past, working back in time by inducing causes from known effects, classifying objects and events by similarity. These are general ideas which explain why forms and events occur. They are theories about energy. In the life-sciences they dominate the study of organisms in relation to their environment: for example in evolution, ecology, economics and sociology.

The second kind of theory works forward in time, deducing effects from known causes, emphasizing differences between forms and events. These are specialized ideas. They are theories about material form, and explain how forms and events occur. In biology they are at root theories of genetic type, and dominate the study of what happens inside organisms: molecular genetics, biochemistry and physiology.

A biologist wishing to discover how organisms work therefore studies molecular and physiological events occurring within the body, as a chemist studies the atoms and molecules of matter. Conversely, those wishing to discover why organisms function as they do study their energetic performances in relation to their environment, just as a physicist studies the energetic relationships between inanimate particles, knowing that the world is a combination of energetic events, rather than a collection of material forms. By searching for new, earlier, more original causes the physicist may arrive at more fundamental, general theories than the chemist. So, in the living world, biologists formulate more fundamental and general theories by asking why rather than how, and studying energetic performance in the natural environment, not material form in the laboratory.

Contemporary biological theory favours a genetic – rather than energetic – epistemology, stipulating that information passes from gene to protein by molecular instruction, and cannot return. But it can: information passes from protein to gene when natural death-selection of some organisms alters the range of genetic diversity amongst survivors. In this way genetic causes arise from proteinous effects according to energetic criteria, in the same way that numbers can be used to analyse and test verbal propositions. Information passes from gene to protein by molecular instruction, and back again from protein to gene by energetic selection. Thus genetic

changes cause evolution but natural selection directs it, just as in the mind evidence allows but does not generate ideas.

These energetic criteria for inducing causes from known effects constitute the currency in which we can formulate a general theory of organic development. Thus, although the growth of individual organisms, evolution of species, and succession of communities of wild animals and plants have different material causes, they share the same energetic cause. Energetic efficiency is the sole criterion of successful performance in all these processes, as well as in the evolution of ideas and development of civilizations.

Species, ideas and cultures evolve in equable conditions by specializing – by genetically assuming more about how to control a larger proportion of a smaller amount of energy. They improve, maintain, or minimize any reduction in their energetic efficiencies by reducing their costs.

Conversely, species, ideas and cultures evolve in catastrophic conditions by becoming more versatile – by genetically assuming less about how to control a smaller proportion of a larger amount of energy. They improve, maintain, or minimize any reduction in their energetic efficiencies by increasing their benefits.

## EVOLUTION OF SPECIES

Organisms have evolved into an immense variety of material forms, but always according to the single energetic criterion of sustaining or improving an efficient performance. Those which control energy more efficiently than others are 'fit', and hence more likely to survive, whereas less efficient organisms die (are 'naturally selected') before they rear offspring.

Organisms become more efficient and minimize any diminution in their efficiency by altering their genes to become either more specialized or more versatile. In equable conditions, organisms compete with each other for environmental energy, making it more expensive to control, so reducing their efficiency. Therefore they evolve by specializing – by genetically assuming more about how to control a larger proportion of a smaller amount of energy. By reducing the range of energetic sources which they control, specialists curb their competitive costs and so maintain or improve

their efficiency. They become big fish in a small energetic pool, and depend for their livelihoods on circumstances created by other organisms. Specialists tend to spend less of their budget on reproducing, being long-lived and reproducing less often. They evolve slowly and gradually. Few new genetic types survive because competitions make energy expensive to control.

When translated into proteins, genes instruct organisms how to control energy efficiently in circumstances which their ancestors repeatedly encountered and are therefore likely to recur in future. But organisms can genetically anticipate only those environmental changes which are of constant magnitude and recur regularly. They cannot anticipate unprecedented or secular changes.

Organisms evolve in catastrophic conditions by becoming more versatile. Catastrophes are unprecedented events which organisms cannot genetically anticipate. Unlike competitions, catastrophes are features of the inorganic environment. They reduce or destroy previously adequate sources of energy, and kill any organisms too specialized to adapt to the new conditions. But catastrophes also make a lot of environmental energy suddenly available to organisms which can adapt by becoming more versatile – by genetically assuming less about how to control a smaller proportion of a larger amount of new sources of environmental energy not controlled by other organisms. By extending the range of sources from which they can control energy, versatile organisms increase their energetic benefits, and so maintain or improve their efficiency, promoting their survival. They become small fish in a big energetic pool, living relatively independently of other organisms. Fewer events take these organisms by surprise.

Versatile organisms evolve rapidly and radically, and many genetic innovations can survive in the new affluence because by drastically altering conditions, catastrophes liberate a lot of energy previously controlled by specialists, making energy abundant and cheap. Moreover, whereas competitions cause the death (natural selection) only of less efficient organisms, catastrophes cause a more capricious natural death-selection, in which organisms of any kind may die, leaving a more genetically variable population of survivors. Versatile organisms tend to lead short lives and spend much of their energy reproducing. Energy is cheap, so they can afford to spend more for quick results. They are less efficient than specialists, but

they live in less equable circumstances. And by breeding frequently and prolifically, the plentiful genetic recombinations enable some of their offspring to adapt successfully to the varying conditions.

Increased versatility and specialization may both increase energetic efficiency, but organisms' efficiencies have not increased inexorably during evolution because specialization may only maintain efficiency in the face of increasingly cut-throat competition, or even merely minimize a reduction in efficiency. And versatile organisms may also paradoxically be less efficient than their antediluvian ancestors would be if they too had survived the catastrophes and were living in the altered contemporary conditions.

During and just after catastrophes, organisms may evolve by neoteny, breeding at a stage of development which in their ancestors was immature. Organisms become more specialized as they grow older, so by evolving neotenuously and omitting the late stages of their ancestors' development they become less specialized and less restricted to particular environmental conditions. Adults of neotenuous species therefore display features which formerly occurred in their immature ancestors, and lose features which their adult ancestors possessed. Some neotenuous organisms breed earlier in their lives, so can afford to die younger. Others may continue to breed at an older age, although at a previously immature stage of development.

Catastrophes are intermittent; therefore so is the evolution of versatility. But these changes are radical when they happen, and neoteny has crucially influenced the course and direction of evolution. Hardy (1954) mentions the following groups as having probably arisen neotenuously: the Siphonophore jellyfish, Ctenophores (Comb Jellies), Cladocera (Water Fleas), the Copepod crustacea, insects, chordates, and within chordates the Larvacea (a class of tunicates, or Sea Squirts), Enteropneustans (Acorn Worms, allied to tunicates), Cephalochordates (a group of chordates including Amphioxus), some lampreys, the recent Dipnoi (Lung-fishes), Urodela (newts and salamanders), Monotremes (the Duck-billed Platypus and Spiny Anteaters), and man himself. To these might be added molluscs, nematodes and rotifers (Medawar, 1955), mosses and liverworts, flowering plants, and the evolution of grasses, sedges and rushes from other flowering plants (Takhtajan, 1959). So, far from being an evolutionary anomaly, neoteny has been crucially important in the evolution of many groups of organisms, establishing entirely new types of organism which by

subsequently specializing proliferate into a great variety of similar species. Catastrophes break the evolutionary mould at intervals; competitions lead to small modifications of the new creations.

Neoteny is rapid and radical, for organisms which have evolved neotenuously do not express a lot of the obsolete genetic information pertaining to the later life they now no longer lead. Consequently, neoteny accounts for 'gaps' in the fossil record (which are not gaps at all), and hence for the distinct phyla, classes, orders, etc., where few or no intermediates exist between groups of very different organisms.

Evolutionists often puzzle over how an organ such as an eye can evolve, since half an eye is useless, and it seems highly improbable that an eyeless animal could evolve eyes at one stroke. However, such organs can appear by the opposite type of evolution to neoteny, when organisms specialize and develop extra stages of development and associated features. For example, in embryonic vertebrates two groups of cells – the incipient eyes – grow out from the brain to each side of the head. If the vertebrates' adult ancestors developed similar rudimentary structures with light-sensitive pigments they would have been able to discern colours, shades, and movements: obvious advantages. The awesome refinements of lenses, muscles for swivelling the eyeballs, etc., could evolve later and in their own time. An eye lacking these luxuries is not useless and does not constitute half an eye.

Natural death-selection is a convincing energetic cause of evolution, but the notion that myriads of mutations are evolution's genetic cause may be merely a myth. The biggest evolutionary changes have probably been the result of natural selection of genetic recombinations generated from sexual breeding in the wake of catastrophes, rather than of mutations after competitions between specialists. Moreover, new genetic combinations need not arise only from sexual breeding; viruses may transfer complete genes from any cell of one organism to the gametes of other organisms of the same or different species. Thus, while neoteny may account for the sudden loss of complete organs and metabolic pathways, genetic recombinations and transfers may account for their sudden acquisition.

Plants which are very similar in appearance but have different numbers of chromosomes may be unable to interbreed and yield efficient, fertile offspring. However, a plant with two sets of chromosomes may evolve

into one with four sets when its chromosomes fail to divide and separate after genetic fusion following sexual fertilization. Alternatively, a nearly sterile hybrid may double its chromosomes and become more fertile – a new 'hybrid' species. By this means, new species may appear, not gradually over a long time by means of many mutations, but suddenly by means of genetic recombination and multiplication. Some of the most widespread and abundant plants have probably evolved in this way, for example Annual Meadow-grass (*Poa annua*) and Bird's Foot Trefoil (*Lotus corniculatus*).

The growth of organisms is environmentally directed and genetically limited, but sexuality extends these genetic limits. Sexual reproduction increases the genetic repertoires of individuals by recombining genes so that sexual organisms become more versatile by modifying their genetic expressions, and they can adapt to changing circumstances during their development much more than asexual organisms. Sex is thus a way of maintaining and improving efficiency. Asexual organisms cannot recombine their genes, so if any conditions arise other than those to which they are adapted, they may become inefficient and die prematurely.

Since organisms usually breed only with others of the same species, which have a very high proportion of their genes in common with each other, sexual breeding sacrifices little individuality, and the popular evolutionary adage that offspring have only half of their genes in common with each parent is not even approximately true. Even so, sexual breeding endows individuals with a large repertoire of genetic talent, and their offspring are more likely to possess the most appropriate genetic instructions for living in whatever conditions they encounter. And rather as sexually breeding organisms can live in a wider range of conditions than can asexual organisms, warm-blooded animals can remain active in a much wider range of conditions than animals which cannot maintain fairly constant temperatures in their bodies – a benefit which may more than offset their increased metabolic costs.

When Darwin formulated his theory of natural selection, his attention was caught by the human selection of crops and domestic animals, where man chooses (selects) certain organisms for breeding, and discards the rest. But in the wild it is the other way about: some organisms die before breeding, leaving others to survive and breed. Thus, Darwin sought

an analogy where an analogy is only confusing. Natural selection is not the survival of the fittest, but the premature death of the less efficient, in consequence of which the more efficient prosper and breed.

Darwin's theory of evolution has itself evolved since the 19th century. Darwin thought of survival in the sense of an individual organism living for a long time, and he used the word 'fittest' to mean 'most able to carry out the ordinary transactions of life', such as running, collecting food, etc. (Waddington, 1968), equating fitness with 'usefulness', in the same sense that animal and plant breeders select in the organisms they rear traits which are useful to mankind. The modern meanings of survival and fitness are quite different. For survival neo-Darwinists mean reproductive success, and by fittest they mean most effective in contributing genes to the next generation. Emphasis changed from the survival of individual organisms to survival of species, and was matched by three changes of paradigm in evolutionary theory. In the early years of the 20th century, evolutionists spoke of individual genes in individual organisms, but by the 1930s neo-Darwinists thought in terms of individual genes in populations of organisms. And in the post-war years, evolutionists have studied populations of genes in populations of organisms (Waddington, 1975).

In the late 19th and early 20th centuries, a protracted controversy arose between naturalists and geneticists about whether evolutionary changes were gradual or sudden. Naturalists saw a constant struggle to survive the forces of natural selection in the wild. This resulted (by some unspecified mechanism) in slow, gradual evolutionary changes, and hence in the existence of continuously variable forms. Unfortunately, of course, naturalists found discontinuously variable species. Geneticists, on the other hand, thought that distinct new species evolved as a result of sudden genetic changes. No intermediate forms were to be found because they did not and never had existed. Therefore different species showed discontinuities in the variability of equivalent features. This conflict between sudden saltation and gradual change – between 'shift' and 'drift' – was not resolved until the 1930s, when neo-Darwinism (the 'modern synthesis') acknowledged that both could be true: the sudden appearance of new species by wholesale genetic changes, and more gradual changes brought about by natural selection. Indeed, so complete was the reconciliation between the two camps that point-mutations of single nucleic acids in genetic material

were invoked to support the notion of intermediate forms ('missing links') in the fossil record, and bolster support for gradual evolution at a leisurely pace throughout the ages.

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Evolving by changing inheritable genes, followed by natural death-selection is a lottery for organisms because the connection between a genetic change and its energetic consequences is arbitrary, and many genetic changes confer disadvantages rather than enabling organisms to survive and thrive. So rather than expose themselves unnecessarily to genetic roulette, organisms may take advantage of three less dangerous alternatives to evolution when conditions change:

1. SECULAR ECOLOGICAL SUCCESSION: organisms move in order to live elsewhere rather than remain and try to survive in conditions which have become unsuitable for them.
2. GROWTH: organisms which have inherited a varied genetic payload from sexually breeding stock can modify expression of some of their genes according to the environmental conditions they encounter. The same happens when species mount immune responses to infections by other organisms. Genes in the infected organism's lymphatic tissues produce a multitude of different proteins in response to an infection, some of which successfully suppress the threat to well-being, and so avert death.
3. IDEAS: similar genetic changes may occur in cerebral tissues, enabling people to find or create favourable environmental conditions and avoid or alleviate unfavourable ones. Like immune responses, thought may entail arbitrary genetic changes followed by winnowing of ineffective proteins, which perish in place of the person, leaving extant ideas which help to improve or maintain or minimize reduction of that individual's efficiency.

The same principle of increasing efficiency by specializing in competitive conditions and becoming more versatile in catastrophic conditions constrains the growth and development of individuals, the succession and regression of natural communities of organisms, and the succession and evolution of human societies. Civilizations develop when 'the amount of

energy harnessed per capita per year increases, or as the efficiency ... of controlling energy is increased, or both.' (White, 1959). This happens by a combination of the evolution of ideas and the succession and regression of societies, as people move around and take their ideas with them. Plato (c. 375 BC) thought that all societies proceed through a succession of competitive timarchy, wealthy oligarchy, liberal democracy, and tyranny. But the complete succession from timarchy to tyranny seldom occurs because it is subject to catastrophes as well as competitions, and may proceed at any pace, pause at any stage, and regress to any extent.

Furthermore, ideas (and the languages which express them) also seem to evolve by becoming more specialized in competitive conditions and more versatile in catastrophic conditions. The growth and development of individual organisms, of natural communities of plants and animals, and of human societies all show similarities because organisms, natural communities, and human societies all change in order to sustain or improve their energetic efficiencies in the face of changing environmental conditions. In each of these processes catastrophes increase versatility and competitions increase specialization, and hence efficiency.

Organisms, natural communities, and human societies become bigger and more specialized as they develop to maturity. After reaching maturity they senesce as they control energy less and less efficiently. The growth of organisms differs from the development of natural communities and human societies insofar as many organisms become both more specialized and versatile as they grow to maturity, and breed when they are living most efficiently or have previously acquired control of a sufficient store of energy. A simultaneous increase in versatility and specialization never occurs in the succession of natural communities and rarely happens in the development of human societies.

#### SECULAR SUCCESSION OF COMMUNITIES

When a site is disturbed – for example when trees are felled, or vegetation burnt, or soil ploughed – many species of plants and animals which had been living there die or leave. Other species move in to take advantage of the new conditions. Indeed, a succession of species continues to occupy

and vacate the site: herbs colonize and before long cover the bare earth; then shrubs appear, and if no further disturbances (such as grazing, or fires) occur, a forest eventually grows up. And as the plants living on the site change, so do the animals.

Organisms which first colonize the bare earth tolerate wide and wild fluctuations in temperature, humidity and wind-speed. They must be versatile in order to withstand the often unpredictable changes in conditions. But these pioneers themselves alter the very conditions they need, for as a succession like that from bare earth to forest progresses, the community of organisms living at the site controls in their bodies an ever increasing proportion of the available environmental energy, bringing it under genetic control in their bodies. Pioneering species become less efficient as they alter the living conditions in which they once thrived. Diminishing fluctuations in conditions and more predictable availability of energy create opportunities for other species which could not survive there before the pioneers arrived, but now find conditions congenial. These move in, and their presence and activities further alter conditions, which become too competitive for the pioneers, who are forced out. For example, large plants may cast shade over smaller plants and so prevent them from thriving. The new residents may be more efficient than the pioneers either because they can acquire more energy or because they manage to keep more of the energy they acquire, or both.

During succession, resident species continually alter old and create new environmental conditions, so that they live less efficiently and newly arriving species can live there more efficiently. These immigrants make conditions increasingly predictable as they control an increasingly large proportion of the available energy. This allows more specialized competitors to replace the more versatile but now less efficient pioneers, who lose in competition and die unless they emigrate and seek a more favourable environment.

Compared with the bare earth on the site earlier, conditions in a forest are equable; trees and shrubs protect much of the community from extremes of wind-speed, humidity and temperature, and fluctuations in the availability of energy become more predictable as it comes under genetic control in the bodies of organisms.

During succession, more specialized organisms control a larger proportion of a smaller amount of available energy, so some are larger but rarer

than their predecessors. They live longer, reproduce less and use the energy they have more efficiently. Organisms of the same species space themselves out so they do not hinder each other in getting and using food and space. They tend to depend for their livelihoods on conditions and opportunities created by organisms of other species living in the community.

Conditions become increasingly competitive as successions progress, and competitors become increasingly specialized. Conversely, regressions occur when environmental catastrophes alter the sources of energy which are available to organisms, forcing many species to leave and so causing a net exodus, with more energy controlled in bodily tissue leaving the community than entering it. During and after catastrophes, specialized organisms make unwarranted genetic assumptions and energetic blunders in less predictable conditions. They die or emigrate, giving way to more versatile species which are more efficient in the new conditions. These versatile species are less efficient than their predecessors were in the previous conditions, but more efficient than their predecessors would be if they still lived there.

A secular ecological succession begins after each catastrophic regression or local extinction, with increasingly specialized species replacing the generalists. This succession continues until another catastrophe causes regression again.

Organisms will be arriving at a locality all the time, and others leaving. When no environmental catastrophes occur, the populations of resident species increase, and organisms have to compete harder for energy. This increase in numbers of organisms also creates conditions and circumstances propitious for other species which can perform more competitively. They move in and make conditions still more competitive. All this happens gradually, and often fairly slowly. But at length some organisms suddenly find they can no longer withstand this increased competition, and have to move away. This disrupts the lives of those who depart, but the catastrophic effect on these emigrants is not nearly as widely felt as environmental catastrophes which affect many resident species and cause wholesale regressions. Moreover, daunting and dangerous to negotiate though these migrations which cause secular ecological successions and regressions can be, they are less dreadful than the natural death-selection which drives evolution. At least in succession those who become displaced still have a chance of finding somewhere else to live.

### A NATURAL HISTORY OF THE MIND

'Establishment of Truth depends on the destruction of Falsehood continually', wrote Blake, to which we might add that Establishment of Cause from Effect depends on the destruction of 'Truth' continually. But each of us starts life far short of the intellectual maturity required to discern cause and effect. Our first two years are full of colour, movement, feeling and emotion. We see, hear, smell, taste and feel more vividly than we ever will again. We react to images, sounds and smells around us, our mental world a faithful reflection of the environmental world. We recognize objects and events, but do not understand where they came from or why, or what they will become or cause. We have no past to remember, so cannot interpret the present or anticipate the future by combining into ideas the sensations we experience. We cannot yet sort sense from our sensations. We are sentient but not yet sensible; we understand nothing.

As we grow up, we adapt to conditions in which we live by classifying objects and events. Casualties among our developing ideas enable us to survive and thrive in circumstances which would otherwise have caught us out. With our first two years behind us, we have a past to remember, and become aware of time passing as we recognize objects and events we have met before. We associate groups of memories, classifying objects which resemble each other and events which occur together, and link them in temporal sequences of cause and effect. Condorcet (1795), for example, understood that the stages of a child's education ideally follows this natural development and evolution of ideas from images and pictures to abstract, general forms. By adulthood we not only see objects and events, but also imagine connections between them, mapped out in our mind's eye as neural networks of cause and effect.

Just as our bodies become both more versatile and specialized as we grow to maturity, breeding at our most efficient, and senescing thereafter as we become only more specialized, so with our ideas. We are most likely to form radically new ideas during early adulthood, when our minds are at their most versatile. This phase ends with an intellectual menopause, whereafter the mind no longer becomes more versatile, but only more specialized. Any further developments of ideas are modifications by degree rather than changes of kind.

Specialized ideas predict much about a few events, evolving without change of assumptions to explain known phenomena more accurately. General, versatile ideas, on the other hand, evolve by changing assumptions in order to explain previously unexplained phenomena, arising as adaptations when observations or other theories or both expose fallacies or inconsistencies in extant theories.

Specialized ideas classify differences, increasing the number of effects which can be predicted from a cause, whereas general ideas classify by similarities, unearthing new causes and so relegating what were formerly first causes to the status of effects of a new first cause. General ideas link or extend or equate concatenations, connecting previously disparate theories and exposing inconsistencies which lie between and beyond the scopes of specialized theories.

Each person's private mental world is much affected by the surrounding environmental world, and although the circumstances into which we are born no longer exclusively determine prospects for our future, the era and stratum of society in which we are reared do continue to influence powerfully what and how we think, and what we fail to recognize and understand. Contemporary social and economic conditions influence which ideas find favour, and how and how far they develop. Our minds are products of nurture rather than nature. '... Does not society make man, according to the milieu in which he acts, into as many different men as there are varieties in zoology? ... Consequently, just as there are zoological species, there always have been and always will be social species.' (Balzac, 1842).

For example, whereas the immutable laws of nature remain correct irrespective of social conditions, moral codes, economic policies and other ideas which affect peoples' well-being and social behaviour vary with cultural conditions to suit different states of mind. An economic theory should apply in all social conditions, but an economic policy will only be effective in some conditions. Adam Smith advanced his theory of economic laissez-faire and free enterprise in the early years of the Industrial Revolution, when a commerce geared to these principles suited people best (Smith, 1776). Later generations of exploited people sought relief in socialist policies advocating the redistribution of wealth by taxes and subsidies, but did not recognize the discrepancy which had arisen between the reality described by economic theory and the desire which economic

policies seek to make real. Like everyone else, economists often fail to distinguish between the fixed laws of nature and the fickle ones of humankind, between what is and what they would like and believe ought to be.

For most of the time, while social conditions fluctuate predictably, we accept the prevailing payload of ideas and classifications which contemporary society imposes on us, content to deduce new effects from known causes which we take for granted. As the Earth remorselessly grinds out the days and years, endlessly spinning round its axis on its orbit through space, our mental world of causes attunes itself to the environmental world of effects, shadowing the rhythms of nature, successfully anticipating how, when and where objects will appear and events unfold with the passing of time. Our ideas and attitudes develop conservatively, by degree, in line with anticipated environmental circumstances. Convictions dominate our orthodox minds, conventions our behaviour, and conformity our ordinary lives. We accept society's wisdom, bound by its customs and brainwashed by its attitudes and ideas. We do not conceive most of our ideas ourselves, but absorb them pre-packaged from other people. From parents and peers, mentors and media, in conversation, in classrooms, on screens and in literature – in every instance a cause is provided and we learn its effects. Far from introducing new causes to reinterpret our environment, we become passive pawns in a pedagogue's world, as our institutionalized minds faithfully replay culturally inculcated ideas.

Occasionally, however, unexpected environmental changes – catastrophes – disrupt the harmony between our private mental world and the public environmental world of society, creating discrepancies between environmental reality and what we expect to find, compelling us to invent new causes for familiar effects. No longer can we confidently and accurately predict how and when events happen, or where objects occur. We may have to move away and make a new start elsewhere if we do not change our ideas and ways, or if we change them inappropriately. Disturbed from familiar circumstances, deprived of normal social adjustments, our mental world dislocates from the surrounding environmental world. It departs the socially inured bounds of time and space, reversing the inexorable passage of time in the environmental world, searching back in time to new causes of known effects, restoring our abilities to anticipate the rhythms of nature.

Having escaped the body's parochial constraints of time and place, the independent mind eclectically searches for ideas trawled from every subject, civilization, and era, developing a love of the origin and embryology of ideas, of their forms, beauty, and connections with each other, selecting from a recipe of images and a menu of descriptions, painting in the mind's eye a limitless abstract vision of the world around it.

Theories which lie in the public domain develop along similar lines to an individual's ideas. Changes in the availability and cost of environmental energy influence the succession and regression of societies and also the kind and acuity of ideas which form and the pace at which they develop. Ideas become general when catastrophes make energy abundant and cheap, and more specialized when competition makes energy scarce and expensive. But when, as seldom happens, catastrophes and competitions occur together, ideas become both general and specialized, and language both exoteric and precise. This happens in renaissances, when people are forced to make livings in entirely new ways, trading materials and ideas at the same time, struggling to do so as if they were competing, but also suffering a social dislocation which teaches them not to trust or accept other peoples' ideas.

Specialized ideas appear at all times, for there are few circumstances in which specialists cannot live comfortably. But general ideas change only in the transitory conditions of opportunity after catastrophes, demanding a spiritual independence careless of prevailing economic constraints, and a mental versatility indifferent to the accepted limits of extant theories and attitudes. At other times, general ideas exist as unalterable assumptions, the foundation upon which specialized ideas depend and from which they derive.

Freud proposed (as Haeckel did for organisms' material forms) that the development of an individual's ideas recapitulates the development of ideas in history – that 'the psychic development of the individual is a short repetition of the course of the development of the race.' (Freud, 1910). The two processes do share many features because they share a common cause, but the intellectual development of an individual is not a consequence or effect of the development of his race.

Nevertheless, poets and artists flourish in unspecialized times, when the mind can most easily create uncluttered pictures and visions of the

world. Vico (1744) compared the vivid imaginations of children with those of adults in the 'childhood of the world', when they formed the most vivid poetic images. 'Images ... are the primitive instruments of thought. Hence ... Early poetry ... [told] a daring deed, a glorious achievement, without caring what went before.' (Eliot, 1884). Rich in images, the ability to abstract comes later in the development of individuals and civilizations alike.

The pictorial images of poetry give way to abstract ideas later in the development of civilizations. 'If the [Ancient] Greeks triumphed over the barbarians ... It is due to the fact that the savages loved garish colours and the blatant noise of the drum, which appealed to their senses, while the Greeks loved intellectual beauty hidden behind sensible beauty ... which gives certainty and strength to the intelligence.' (Poincaré, 1908). Thus, ideas succeed one another and evolve as civilizations develop and mature very much as they do in the minds of individuals as they grow to maturity.

The development of languages, like that of ideas, is dominated by the evolution of abstract terms, of metaphors which become increasingly further removed from their original sentient imitations. 'Examples come easily to mind: the evolution from counting in words to Roman numerals (a semi-verbal, clumsy half-algorithm) to Arabic notation with position[al] value; equations, from verbal formulation to rudimentary symbolism handled with virtuosity (but difficult for us to follow) by Diophantus and other founders of algebra, to modern notation.' (von Bertalanffy, 1968). The theories of ecology arose from the observations of natural history as methods of studying communities of organisms developed. Writing began in pictorial form, and speech was probably onomatopoeic; later they became conventionalized into alphabets. Money has likewise evolved from iconic to abstract forms of the energy it represents. Hence energetic efficiency determines economic performance, and the rules of survival in natural communities apply in human societies in all economic conditions.

General and specialized ideas form prolifically when energy is abundant but expensive. Conversely, scarce energy and economic poverty predispose to intellectual poverty. People and their cultures may only survive in these conditions by being religious – by accepting traditional theories and customs without question, so that they think and therefore act alike, towards the same ends at the same times. This behavioural coordination

reduces costs and increases efficiency, but at the expense of independent thought, for that may lead to independent action. People cannot reconcile what they would like to happen with what they know will actually happen, so they do not think what they believe. This would increase their personal costs, reducing efficiency, and so threaten their survival.

It would be a mistake to think of reason invariably succeeding belief by virtue of superior performance. History shows that this does not happen, for time and evolution do not proceed exactly apace; progress is neither steady nor continuous, either in organic evolution or in the development of ideas and cultures. 'In the 5th century BC the educated classes knew that the earth was a spherical body floating in space and spinning round its axis; a thousand years later they thought it was a flat disc.' (Koestler, 1964). Darwin knew well enough that individuals struggle for survival; today one hears only of the survival of species.

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It is easy and therefore common to specialize, deducing effects from known causes by genetic instruction, simulating sequences of environmental events. But it is hard and therefore rare to become mentally versatile, thinking back by energetic selection to earlier, original causes, the start of time, labour of the universal mind. While the naturalist's eye may delight in the variety of nature, the biologist's mind delights in its uniformity, leading us not into the future, realm of the technologist, with explanations of how events occur, but back into the past, the difference between developing our acquired intellect rather than encumbering our innate intelligence, revealing beauty as a property not of material forms but of the ideas anticipating and energy connecting them. By discovering new causes for observable effects, the present becomes our key to understanding the past, wherefore the nature of history reveals the history of nature. We study the present state of nature in order to understand its history, and the history of humankind in order to understand our present condition and anticipate our eventual fate.

We like to simplify our world. Art simplifies its appearance. Sport simplifies the rules and results. Science simplifies the structure and behaviour of objects and events by classifying them as cause and effect.

Indeed, all biology's most interesting problems are at root difficulties of language ... of representing the infinite variety of developing forms in nature as a minimal number of causes in the mind, linking past and present in endless ribbons of time, so that we may understand as well as enjoy a myriad of organic effects as they appear on the world's stage, flourish, and fade into the past.

## 6. NATURAL HISTORY IN THE 21ST CENTURY

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BY THE LATER DECADES of the 19th century natural history had ceded to biology pole position in developing man's understanding of the living world. Natural history remained a pastime for the comfortably off in the countryside, such as the army of clergymen who dovetailed their interests in natural history with the leisurely routine of provincial professional life. But for scientists in more industrialized working environments – members of one of the first generations to become isolated from the daily and seasonal rhythms of rural life – biological research had moved far beyond the realm of natural history.

Victorian naturalists, with the clergy prominent among their numbers, clung to the notion of a celestial explanation for the multiplicity of species, and interested themselves only in the effects which species manifest: what they look like and how they behave. Latterly, one ideological mantra merely gave way to another as Evolution on Earth replaced God in Heaven as the original cause of organic diversity. Where formerly the notion of God had explained everything, and the only remaining task was to compile a comprehensive inventory of His wonderful effects, latterday naturalists have merely replaced God with biological theory, which they

take on trust as completely as their forebears believed in The Almighty. Evolution is taught as the cause of organic diversity, and teachers devote the syllabus to studying this diversity as the modern biological disciplines of comparative anatomy, physiology, biochemistry and genetics. Hence orthodox students learn how organisms function. Provided with a causal explanation – evolution – they study its effects. They are not invited to wonder what causes evolution, and why it does so.

Nevertheless, when biologists forsook God for evolution as the cause of organic diversity they began to look for corroborative evidence. Their endless quest to replace God with physiological, biochemical, genetic and ecological causes which explain why animals and plants look like, live where, behave, and differ as they do drives biologists to search for similarities between species – features which unite them all in the brotherhood of organic endeavour. Biologists seek the uniformity in nature which underlies its diversity. Natural historians, on the other hand, want to distinguish species and so are more interested in differences between their material forms and life-cycles, activities and life-styles. Naturalists study the diversity of nature, whereas biologists look for the causes of this diversity, restoring to the natural world an orderliness which was lost with The Almighty's fall from intellectual grace. Biologists take little interest in the diversity of nature and differences between species. Preoccupied with causes, they no more wish to investigate the multifarious effects of the struggle to survive than naturalists feel a need to investigate its causes.

Problems of definition arise from this obsession of scientists with the general rather than particular. For example, whereas a naturalist asks 'Which species is that?', biologists would ask 'What is a species?' And whereas naturalists devise and use keys and field-guides in order to recognize and distinguish species, biologists take more interest in classifying species by ranking them in hierarchical tiers of genera, families, orders, classes, etc., according to their shared similarities and putative evolutionary affinities.

When a naturalist glimpses a bird in the trees, he immediately calls to mind a complete picture of that bird, as if it were right before his eyes with every detail visible; also a picture of what the bird eats, where it nests, whether it migrates. The biologist carries this abstraction further: starting with the naturalist's lore about the bird, he adds many genetic, anatomical, metabolic and ecological features shared by all the birds belonging to that

species. Furthermore, he classifies this species with other similar species, and by doing this according to evolutionary affinity he calls to mind a maximum number of shared features.

Again, when ecologists construct food-webs, classifying groups of species according to their shared abilities to control energy within natural communities, they simplify the ways in which species are perceived to make their livings, just as naturalists and biologists infer similarities between species when grouping them together in hierarchical evolutionary classifications, and then assume similarities in their life-cycles. Plants, for example, are 'primary producers'; sharks and hawks are 'top carnivores', and so on. These ecological classifications of performance mirror evolutionary classifications of anatomical form, material looks and metabolic behaviour, for species which share recent evolutionary ancestors also share a high proportion of genetic instructions, material and metabolic characteristics, and tend to make their livings in similar ways. For example, all the fungal species in a woodland which digest the remains of dead animals and plants are (in ecologists' parlance) saprophytes, feeding on and recycling organic detritus, consigned to one compartment of the woodland's food-web. But each of these fungal species digests the remains of particular species of animals and plants at different stages of decomposition. And each fungal species is most active at particular times of year, so that secular ('ecological') and cyclical seasonal successions occur at the same time and in the same places. Each fungal species has a unique ecological occupation, yet one recognizably similar to those of other fungi, just as each species possesses unique features in its appearance, while also sharing many material features with other fungi.

This preference of biologists for studying similarities between organisms rather than their differences is a fundamental distinction between natural science and natural history. While natural historians continue to search for effects of an original cause – divine at first, now ecological and evolutionary – for biologists the novelty of distinguishing and describing species has in large measure worn off. For them, the diversity of nature is now passé; instead their heads are turned by the underlying uniformity of nature. They want answers to the evolutionary question 'Why are there so many different kinds of animals and plants?' and the ecological question 'Why do they look like and live as they do?'

Biologists' philosophical fascination for discovering patterns in nature and identifying similarities between forms and events has beguiled them into assuming that because the protean organic processes of the growth of organisms, evolution of species and secular ecological succession of communities share energetic traits and trends common to all three processes, they also share a common material cause. Just as Vico (1744) pointed out that the minds of children, poets, and primitive people respectively represent the early stages of intellectual development in the growth of individuals and the cultural evolution and succession of societies, so biologists compare the material developments of organisms, species and communities. In doing so they confuse the effects of growth, evolution and succession. Naturalists in the 21st century may eliminate much of this confusion by further elucidating organisms' life-cycles and life-styles.

Unlike biologists, natural historians pay no attention to the causes of growth, evolution and succession. They are more interested in the visible diversity of animals and plants than in theories about why and how they look like and live as they do. As an unfortunate consequence of their attitude, many naturalists do not know how organisms' features change as they develop to maturity. Naturalists therefore cannot be sure which of the variations they find in organisms' features at any particular time are intraspecific changes during growth of individual organisms and which are interspecific changes caused by evolution of species. And similarly, do variations in the appearances of organisms at any particular place manifest the evolution of species or succession of communities?

For these reasons, then, while biologists erroneously assume that growth, evolution and secular succession must share the same material cause simply because they share an energetic cause, naturalists erroneously assume that they correctly distinguish spatial and temporal variations in the features and activities of organisms as effects of growth, evolution or secular succession. But nothing could be further from the truth. Indeed, it is all too easy to confuse variations between organic forms in time and place caused by growth, evolution and succession, and biologists and naturalists alike may agree with Buffon and Lamarck that 'in nature there are only individuals: genera, orders and classes exist only in our imagination'; likewise species and communities of species are constructions of our mental world, not constituents of the environmental world.

## GROWTH AND LIFE-CYCLES

There are three reasons why naturalists did not confuse growth with evolution before the late 18th century. First, travel was laborious and expensive, so naturalists spent much of their time studying wildlife near their own homes. They passed the same hedgebanks each day, watching individual plants grow from seedlings into mature plants, set seed, and die back. They collected insects and grew them on in the conservatory, watching them lay eggs, hatch into larvae, pupate, and emerge as adults. By studying at first hand how the features of individual animals and plants change as they pass through their lives, and how their life-cycles were in tune with the seasonal cycle, these old-time naturalists of yesteryear became more familiar with the growth and life-cycles of common plants and animals than did many of their latterday successors.

A second reason why pre-industrial naturalists did not confuse growth and evolution is that they did not conceptualize evolution. They had no accurate notion of the age of the Earth or of fossils. In the 19th century, though, the volume of traffic and ease of travel increased as a result of the Industrial Revolution, and people became much more aware of and curious about how the features of animals and plants vary from one place to another, and change as time passes. At the end of the 18th century, as naturalists began to realize that extant species had not all formerly existed alongside extinct species, Buffon, Goethe and Erasmus Darwin speculated that species may have arisen afresh throughout time. Then Cuvier and other naturalists of the early 19th century began to gather compelling evidence that species had evolved from and into other species, and it became apparent that the evolution of species shows traits and trends similar to the growth and development of individual organisms. Kilmeyer, in 1793, seems to have been the first to remark on similarities between stages of development in the lives of individual organisms and the order in which different classes of animals and plants are presumed to have come into existence in the past. The associated idea that embryonic forms of extant species with similar adult forms exhibit features once possessed by the adult form of an extinct ancestral species can be traced via E.R.A. Serres, Geoffroy St Hilaire, J.F. Meckel and K. von Baer to E. Haeckel (Appel, 1987), and stimulated speculation about why similar trends occur in the

growth of individual organisms and the evolution of species. What causes their similarities? Haeckel (1866) suggested that embryonic and immature organisms re-enact their evolution from ancestral species. Garstang (1951) suggested the reverse: that phylogeny repeats ontogeny. Thus, from about the early 19th century, biologists were thoroughly confused by similarities shared by the growth of organisms and evolution of species.

The third reason why pre-industrial naturalists did not confuse the variability of growth with variations of evolution is that they mostly studied large, conspicuous animals and plants: vascular plants, vertebrates and conspicuous invertebrates. Most of these breed sexually (and many behave ostentatiously when doing so), making it easy for naturalists to study their life-cycles and variability of features as they grow to maturity. Since prehistory, naturalists have recognized distinct kinds of these organisms by the same conspicuous sexual or sexually associated features which the organisms themselves use (directly or indirectly) to sexually recognize and breed with other organisms of the same species: the scent and colours of flowers, the song and plumage of birds, or markings on the wings of butterflies. Naturalists therefore not only made few errors in distinguishing and delimiting species of vertebrates, large lepidoptera and flowering plants, they also found it easier to refine these species in the wild and observe how their features change in the course of their lives. Furthermore, naturalists may better and more accurately distinguish species by their sexual features because these persist only for limited periods of organisms' lives, and are therefore less likely to change with age in the way that many long-lasting non-sexual features do.

Early naturalists also noticed many of the larger animals mating in the wild, like only with like kind, and doubtless inferred that plants also breed like only with like kind, and faithfully reproduce like again. Perhaps they also realized that sexual identification and choice of breeding partner determine the material forms of offspring, which in turn influence their energetic performances. But they did not know that some organisms closely resemble each other because they exchange inherited traits when they interbreed, and share them as a consequence.

Early naturalists often used slack criteria for distinguishing and delimiting species. When they noticed animals and plants they had not seen before, they doubtless thought – just as we might today – ‘That looks

different to other, similar organisms. It must be a different kind.’ The naturalist collected his specimen, took it home, described it, and gave it a name. He published his description and the new name, and deposited the preserved specimen in a cabinet or herbarium. This original recognition of a species depended upon the naturalist's ability to perceive a difference either of kind or of degree in the features shown by his new find, when compared with similar types of organism. If the difference was one of degree, the naturalist must have intuitively realized that there existed a discontinuity in the variation of one or more features shown by his new species when compared with similar species. However, all subsequent identifications of that species depend entirely upon the description of the one collection and the naturalist's original justification for distinguishing it from other similar species. His skill and experience become lost in (or his error and naivety become part of) the process of defining and distinguishing the new species exclusively on the basis of one or a few specimens collected from one place at one time. No longer is the new species perceived as varying within certain limits, but as existing in one perfectly invariable form – that of the original collection preserved in a museum or herbarium, to which all members of the species are expected to conform exactly.

Early naturalists, imbued with the notion that species came into existence at a single creative stroke, confidently executed the will of God by distinguishing each new species on the strength of one or a few original gatherings. Each of these was (and alone remained) the perfectly correct form of that species. This quirk of taxonomic tradition accommodates the religious preference of bygone times for regarding species as suddenly created and subsequently immutable, and to this day obliterates from naturalists' minds the variability of appearance found within species. Any specimens found which differed from the original collection in any way, however slight, have strayed from the path of systematic fidelity, and are accordingly marked down as aberrant varieties. This delusion created by taxonomic tradition persists nowadays, continually reinforced by the compulsion of naturalists to classify species according to differences between them, persuading us to overlook variation within each species. We pretend that all the individuals of a species look alike, and that variations normally only occur between species. ‘... Just as little do we see a tree exactly and

entire with regard to its leaves, branches, colour, shape; it is so much easier for us to put together an approximation of a tree.' (Nietzsche, 1886). We find it far easier to see all the trees of one species as the same, and ignore differences between them. Even when we encounter a different, unusual species we still fabricate the greater part of what we see, and often fail to recognize it as different, imagining we have seen another, commoner species which we are more accustomed to finding. Moreover, keys for identifying species do not accommodate species which have not previously been found or described, or are known only from far distant countries, so the user tends to identify an unusual organism as belonging to whichever species is the best approximation in the key.

When naturalists described species anew from one or a few specimens collected from one place at one time, they took no account of intraspecific variability of features during growth, and created scope for confusing that variability with differences between organisms belonging to different species. This did not matter with vertebrates, conspicuous invertebrates, and flowering plants because naturalists delimit these species by their sexual features which develop only at maturity and therefore do not vary as much as non-sexual features in the course of an organism's life. But this does not hold true for cryptogams and most invertebrates.

Naturalists pragmatically delimit many species of cryptogam and invertebrate using persistent non-sexual features because their sexual features are inconspicuous and transient, and may not develop at all in conditions where it pays to not breed or to reproduce asexually. The sexual attributes of mosses and liverworts, for example, are inconspicuous and short-lived, and their love-lives so discreet that naturalists identify and delimit these species using more prominent and enduring features such as the shapes and dimensions of their leaves and spore-producing capsules. However, because asexual features persist for longer periods they may vary considerably in shape, size and colour as the organisms grow up and older, or in response to differences or changes in environmental conditions. Differences in these persistent non-sexual features may be consequences of differences in the ages of organisms and the circumstances in which they have been living, rather than of inherited genetic payload. Consequently, naturalists may mistake intraspecific developmental variability for differences between species, and may therefore delimit these species inaccurately and

misidentify them. Moreover, the tautology of delimiting and identifying a moss by virtue of, say, having spores of a particular size may easily prove to be erroneous, as that species can never be found with spores of a different size. If it were, it could not be that species. This is what happens when people study anatomical effects without knowing their sexual or genetic causes, or caring about their ecological consequences. Fascinating scientific enquiries degenerate into sterile semantic squabbles about delimiting and distinguishing species. The result is a taxonomic mess.

As with the flowers of larger plants, the structures and appearances of the sexual organs of mosses and liverworts may only be indirectly pertinent to how these plants sexually recognize others of the same species: flow of water and movements of invertebrates amongst the stems and leaves may carry male gametes to the female sexual organs. Furthermore, their sexual features show few interspecific differences which are visible using a compound microscope, so bryological floras rarely designate species of moss and liverwort by their sexual features.

Natural historians can reliably distinguish similar species only when they find discontinuities in variations of features which organisms themselves use for sexual identification, which match other discontinuities in their non-sexual features and activities. But few species described in floras and field-guides have ever been sufficiently evaluated that we may be confident each delimited species does indeed differ from all others sexually, genetically and ecologically. We take their distinct identities on trust, assuming the existence of undocumented reproductive, genetic, metabolic and ecological discontinuities which correspond to the limits of the species' visible anatomical variability. Manuals of identification (and very often also the literature in which a species was first reported) describe but do not substantiate distinctions between congeneric species, as if the author has presumed the distinctions between similar species. If the finders and describers of these species did ever establish the existence of discontinuities in the features of these organisms, their evidence has long since slipped into taxonomic oblivion, lost in the annals of science and mists of time. Are these distinctions indeed interspecific? Or might they be intraspecific: continuously variable features or polymorphisms either with an inherited genetic cause, or induced by discontinuously variable environmental conditions or events, such as seasonal influences on perennial organisms?

The diminutive sizes and discreet sexual behaviour of cryptogams and many invertebrates have also hindered elucidation of their life-cycles. Being difficult to reliably refind in the wild, naturalists often bring them into cultivation in order to study how their features change as they grow to maturity, the range of environmental conditions they can tolerate, how these conditions affect the organisms' features, and seasonal development of sexual and other features. Such studies enable naturalists to decide the extents to which variability of organisms' features are intraspecific – a consequence either of environmental influence or inherited, genetically determined differences – or interspecific. In turn, this enables naturalists to decide whether similar organisms hitherto designated as different species are indeed distinct, and conversely whether organisms thought of as varieties of the same species are in fact distinct species. However, because conditions in cultivation differ from those in the organisms' native haunts, captive organisms may grow and develop in different ways and at different rates to organisms of the same species living wild, and naturalists may still err when delimiting these species and describing their life-cycles.

The life-cycles of few invertebrates and cryptogams had been elucidated by the time industrialization began to dull the impact of seasonal cycles on the lives of naturalists and travel became cheaper and easier. Rather than check the extent to which non-sexual features of cryptogams and invertebrates vary during their lives, most latterday naturalists prefer to rush through the countryside like roving dilettantes, trying to identify as many species (or what they suppose are distinct species) as possible. They take on trust which features are heritable and which are not, and accept without a second thought the delimitations of species presented in field-guides and floras.

The Industrial Revolution continued to affect and alter the ways in which people thought about and studied nature throughout the 19th and 20th centuries. By the end of the 19th century, for example, biologists had lost interest in natural history and elucidating life-cycles because the laboratory's new toys and techniques furnished fresh and fascinating opportunities to find out how organisms work internally. Physiology, biochemistry, cytology, and then genetics attracted attention and diverted resources from comparative anatomy, taxonomy, and classification. At much the same time (and for the same reason) T.H. Huxley's new science

syllabuses in British schools relegated study of variability within and between species to an extracurricular, educationally and hence also socially marginal status. Instead of learning to identify and distinguish many species, pupils studied a few species, each 'typical' or 'representative', supposedly like all other similar species except for minor details of no consequence. *Funaria hygrometrica*, for example, 'represented' mosses, and *Marchantia polymorpha* 'represented' liverworts. Huxley's initiative was balm to biologists becalmed in the laboratory, for whom organic diversity had become a confounded nuisance, but ideological anathema to naturalists, as it tacitly encouraged the notion that organisms of species which look similar also have similar life-cycles and life-styles, and went a long way towards killing off natural history in the classroom. And the rise of embryology to prominence in biology syllabuses reinforced the notion that groups of similar species share the same stages of development.

Interest in studying the changing forms and activities of organisms as they grow and mature continued to diminish during the first half of the 20th century, as laboratory-based disciplines consolidated their position at the forefront of biological research, and deteriorating socio-economic circumstances in the western world diverted interest from the intricacies of natural form to more pressing concerns about personal well-being. Biology in the laboratory maintained precedence over field-studies after the Second World War, for even though standards of living improved to unprecedented levels for most people in the western world (and interest in natural history resurged accordingly), all the agricultural, medical and other rewards of applied biology stemmed from finding out what happens inside organisms rather than field-based ecology and natural history. Consequently, gaps in our knowledge of differences between the life-cycles of many species (including vertebrates and vascular plants) remain today much as they were in the 19th century. Only for parasites and pests of medical or economic importance did sustained interest further elucidate life-cycles in the 20th century.

Like naturalists, professional biologists also often fail to recognize how much organisms' features vary during growth and maturation, and to distinguish this intraspecific variability from interspecific differences. For example, electrophoresis (the passing of electric current through substances extracted from organisms in order to separate different kinds of

protein and genetic molecules according to their electric charges) has repeatedly shown that all manner of organisms vary intraspecifically, even within one population in a limited area. However, many of these studies rely upon samples from different places, but only at one or a very few times, rather than repeatedly over a period. The variations found are habitually attributed to genetic differences between organisms, but it is equally possible that the individual organisms were at different stages of development when their tissues were sampled, as a result of local variations in environmental conditions rather than because of inherited genetic differences. If so, differences in patterns of growth and differentiation are results of differences of nurture, not nature, with biologists overlooking variations in time, just as naturalists do.

Surreptitiously, then, but with numbing certainty, the lie has entered the Western psyche – pedagogue and pupil alike – that what is true for arbitrary moments and intervals in the lives of species deemed ‘representative’ of others also applies at other times and to other species. In consequence, several generations of people (not only the lay public, but also biology teachers, career biologists, and latterly many professional naturalists) have now grown up and passed into history without knowing the life-cycles of species, much less how to distinguish intraspecific variability in their features from interspecific differences compared with other species.

Comfortable in their conformity to prevailing moral law that all men are equal, naturalists and biologists extended this pernicious lie to the rest of living nature and assumed that all individuals of a species are the same. But by ignoring intraspecific variation they risk confusing variability in features during the growth and development of individual organisms with persistent differences between these organisms and those of other species, confusing growth with the effects of evolution – intraspecific variability with interspecific differences – failing to distinguish the influences of time and space, and the effects of age, nurture and nature on the life-cycles and life-styles of organisms. This is likely to be particularly true of little-studied cryptogams and invertebrates, whose species naturalists rarely delimit according to their sexual features. Naturalists in the 21st century will have their hands full disentangling the long-established confusion between intraspecific variability in organisms’ features during their growth and development to maturity from more enduring interspecific differences

between organisms belonging to different species which are consequences of evolution, not growth, of nature rather than nurture.

#### SECULAR ECOLOGICAL SUCCESSION

By studying organisms’ life-cycles and life-styles more assiduously, naturalists in the 21st century may be less likely to confuse secular with seasonal and diurnal successions, secular successions with evolution, and seasonal successions with growth. The word ‘succession’ has for long referred to regular, periodical, daily and seasonal fluctuations in organisms’ activities, as well as non-periodical (secular) changes over longer spans of time. In the pages below, ‘secular’ succession denotes long-term non-periodical successions, as distinct from daily and seasonal successions.

Secular ecological succession attracted passing notice from Linnaeus and Buffon in the 18th century, and from Augustin-Pyramus de Candolle, Humboldt, Lyell and others in the 19th. Dureau de la Malle (1825), who studied the vegetation of woods and meadows on his estate in France, seems to have been the first to regard secular succession of plant species as ‘a fundamental law imposed on vegetation’, but concerted studies of succession did not begin until the professionalization of ecology at the start of the 20th century. The German naturalist Moritz Wagner (1868) realized that migrations of organisms and subsequent isolation of populations were important causes of evolution, but secular succession has continued to be confused with evolution up to the present day. For example, genetic recombinations following sexual breeding, followed in turn by secular succession and reproductive isolation probably constitute much more important evolutionary causes than do mutations. Thus, when a few individuals of a species disperse, becoming isolated from the main population from which they arose, and breed among themselves sexually, their inheritable features influence the genetic constitutions of their descendants more than if they were still members of the larger parental population, and may come to predominate. Moreover, if environmental conditions differ from those experienced by the parental population, different features will be naturally selected, and a new species will evolve. All this happens by new combinations of extant genes without the need to evolve new genes. The geographical

distributions of species constantly change in response to changing environmental conditions, with small splinter-populations occasionally becoming isolated from their parental populations and developing different characteristics in response to different conditions. However, secular succession may only be an integral part of the evolution of species whose members have become geographically isolated from their parental species.

Evolution may be confused with secular ecological successions which occurred in the long-gone past. Thus, palaeontologists confuse evolution with succession when they regard the fossil record at any particular locality as a record only of evolution. As Cuvier suggested, a fossil record is also – and probably more so – a record of ecological succession: of migrations of animals and plants into and away from each locality. Changes in the kinds of fossilized organisms found in different strata are more likely to be the results of changes in the environment – of immigrations and emigrations, of succession and regression – than of extinctions and evolutionary changes in the organisms themselves. Fossil records often show abrupt changes, for example at stratigraphical unconformities caused by sudden changes in environmental conditions. After these environmental changes, the appearances of species different to those which lived there before is usually attributed to the evolution of new species. But it is more likely to be a consequence of species already in existence elsewhere colonizing the altered habitat. Geographical differences between habitats and communities of animals and plants occurred in bygone geological eras, just as they do now, and at any particular time different species and communities of organisms will have thrived in different places because environmental conditions differed from place to place, as well as changing at each particular place as time passed. Yet palaeontologists regard ‘the’ fossil record as a general record of life everywhere on Earth in bygone times.

‘Geological succession’ refers to the occurrence of layers of different kinds of rocks which were laid down as sediments long ago, one on top of the other, as conditions changed. A fossil ‘succession’ (or ‘record’) in those rocks, on the other hand, is usually thought of as being a consequence of organic evolution, and it is a confusing irony that by succession palaeontologists usually mean evolution rather than secular ecological succession. But a ‘succession’ of fossils in sedimentary strata does indeed refer to a secular ecological succession of species in series of younger rocks overlying

older formations, rather than to evolution of those species. A fossil record only becomes more a record of evolution than succession when considering the chronological appearances of more general classificatory groups such as reptiles, birds and mammals during tens and hundreds of millions of years. A ‘succession’ of smaller groups such as species during shorter periods is much more likely to be precisely that: succession, not evolution. A palaeontologist in the future, studying the British fossil record of the 20th century would conclude that Grey Squirrels replaced Red Squirrels. Was it evolution or succession? Contemporary witnesses know full well that Grey Squirrels did not replace Red Squirrels by evolving from them during the 20th century, but our descendants may conclude otherwise as they study 20th century rocks.

Succession has also repeatedly been confused with growth, as well as with evolution. Whereas palaeontologists confuse secular succession with evolution, ecologists confuse secular succession caused by one-way migrations of species with cyclical diurnal and seasonal successions caused by variations in organisms’ activities as they grow and mature. For example, different species predominate in a field in spring and late summer. Is this seasonal or secular succession or both? Ecologists also overlook diurnal and seasonal variations in energy flowing through communities when they construct food-webs. For example, warblers are prominent insectivores in many woods in summer, but not at other times of year; anemones and bluebells are important ‘primary producers’ in spring, but have died back by autumn, and the larvae of many nocturnal moths do not feed during daylight. In all these examples, a naturalist cannot distinguish diurnal, seasonal and secular successions by analysing what he sees at any particular moment, but only by monitoring changes at any particular place over an extended period of time. Even in professionally organized research, very little effort has been directed at studying temporal fluctuations of organisms’ activities, for there are more glamorous, avant-garde ways of spending research grants and justifying professional salaries and status than patiently describing circadian and circannual variations in environmental conditions and the consequent diurnal and seasonal successions of organisms. Demonstrating such differences in species’ life-styles affects or alters biological theory not one jot. And anyway, who wants to spend their working days watching grass grow?

Secular ecological successions are caused by non-cyclical variations in organisms' activities: for example, the sporulation of pioneering plants when more competitive species move in, or one-way migrations of animals. Seasonal and diurnal successions, on the other hand, are mainly caused by cyclical variations in organisms' activities, such as in the seasonal succession of herbs and insects in a field or wood.

Circadian cycles of activity are usually variations of degree, whereas changes of activity in seasonal and secular successions are often variations of kind, as with hibernating animals and sporulating plants.

To make matters still worse, ecologists also confuse temporal changes during succession with spatial gradations in the distributions of species visible at any particular time: for example, on a seashore between low and high tide-marks, or between low and high altitudes on a mountain, or from the margin of a pool through nearby marsh to dry ground. In this last example, ground which is dry may indeed have formerly been wet, with a community of species similar to that now occupying wet ground nearer the pool, but the gradation of habitat and community visible at a particular time is neither the same as nor evidence of a temporal succession.

#### LIFE-STYLES

Naturalists might also distinguish species more reliably by how each species makes its living, and identify species by their unique life-styles, or ecological niches, as well as by their physical features – by energetic performance as well as material form.

Ecologists, though, think of ecological niches as features of habitat rather than habit – as environmental niches rather than as attributes of organisms. They study environmental features such as wind-speed, humidity, mineral concentrations in soil and water, etc., rather than organisms' metabolic activities and energetic performances, which are more difficult to measure in the field. Moreover, many species of animals move from one environmental niche to another as they pass through their lives – for example, the aquatic larva of an insect which hatches into a terrestrial adult, or tadpole and toad, or a bird which migrates seasonally. So an animal may occupy more than one environmental niche, whereas each species has only one unique ecological niche – its biological biography,

or ecological natural history – which constitutes its performance over a lifetime, rather as financial accounts accurately represent the performance of a business only by spanning several years of trading.

Of all species, parasites (including many fungi, bacteria and viruses) come closest to being recognized and delimited by their life-styles because they live so intimately in or on other organisms. This is particularly so when they live and depend on only one or a few host-species. Their hosts are indeed predominant constituents of their parasites' life-styles but this is mere coincidence for their hosts also form the biggest part of the parasites' environmental niches, and this is what biologists have recognized and described.

Another reason why ecologists find it easier to study environments rather than organisms is that they cannot hope to identify every species in a habitat. Ecologists therefore identify and delimit natural communities by identifying a limited range of whichever group of species constitutes a conspicuous part of the community, and with which they happen to be familiar. These characterizations of communities are tautologous caricatures, little advanced beyond a layman's recognition of habitats: a forest looks different to a bog because different plants grow there. The National Vegetation Classification of Britain identifies different kinds of vegetation (or habitat) using a limited number of species of vascular plants, a few cryptogams, and no animals. Moreover, such classifications of communities would be more informative and representative if based upon temporal flux rather than spatial form – on secular succession rather than inventories of constituent species present at a particular time, and with seasonal succession distinguished from secular succession.

Biologists are more interested in the concept of a hypothetical species and how to define it than in delimiting existing species. They take the same line with 'the' idealized ecological niche, and debate what features this generic concept possesses. They are not interested in how each species' niche differs from all other niches, and pay only perfunctory lip-service to the metabolic and behavioural features which make each species unique. Their point of view is quite different to that of a naturalist, who is not interested in generic, abstract concepts of a hypothetical niche or species, but wants to know how the ecological niche of each species differs from those of all other species.

But is it possible to distinguish species by their activities? Contemporary biological theory stipulates that each species has its own distinctive genetic constitution, anatomical attributes, metabolic repertoire, behavioural mannerisms, and deploys its unique combination of attributes and abilities to make its living differently to all other species, creating and pursuing its own unique life-style (or ecological niche) in nature. Yet each organism's features, activities, and circumstances change as the days, seasons, and years go by, so its performance at any particular time constitutes only a part of its ecological niche. So although a naturalist may identify a species by its appearance and behaviour at whichever moment he encounters it, these attributes neither constitute nor enable him to understand that species' unique life-style.

Since, moreover, biologists and naturalists recognize species much more readily by their visible attributes than by their working lives, the assumption that each species' ecological niche is discrete and unique remains to be substantiated. Indeed, we do not yet know whether species can be distinguished and characterized exclusively in terms of their activities, without mention of their forms and conformations. How do their ecological niches differ? Do their boundaries correspond to those traditionally recognized between species?

Biologists assume that each species evolved into a form and way of life which enables it to live in circumstances and exploit resources which are either unavailable or less accessible to other species. But is the ecological niche of each species unique, like its form? Is it possible to distinguish a species not only by its looks, but also by how and where and when it controls energy – by its repertoire of behavioural adaptations and the resources of energy which it manipulates? Is it possible to match interspecific discontinuities in visible material form with distinct life-styles, recognizing and describing species by how, where and when they make their livings as well as by their genetic inheritances and material looks, matching each species' unique evolutionary form with its unique ecological performance?

In our present state of ignorance it is certainly very difficult to describe and identify most species by what they do, rather than by what they look like. For example, can you unambiguously describe a robin without referring to its visible or audible features? Do daisies and dandelions in your lawn make their livings differently, and if so how?

Naturalists find it difficult or impossible to describe nutritional aspects of plants' life-styles because they cannot observe how their roots assimilate nutrients from soil. Such metabolic studies not only lie beyond the means of amateur naturalists, but of many professional ecologists too. Zoologists face similar difficulties in identifying how each species of animal uses the nutrients in its food. Even identifying which species an animal eats can be difficult. Conspicuous insects such as butterflies have well documented diets because their larvae are easy to approach closely, so entomologists can see what they eat. Moreover, they normally eat only one or a few species, and their diets vary little or not at all as time passes. But the dietary, nutritional and other metabolic aspects of most other species' ecological niches are difficult to elucidate, and currently lie beyond the realms of feasible amateur study. Birds, for example, despite being conspicuous, familiar and popular to observe, are difficult to approach closely enough to accurately identify which species of plant or animal they consume. Furthermore, their diets change with the seasons, and may even do so with the time of day. Therefore many of the diurnal and seasonal variations in the diets of birds are poorly known.

However, naturalists can easily elucidate another aspect of species' ecological niches: how they 'time-share' their environmental resources by acquiring, controlling, and releasing energy in daily and seasonal successions of activity according to their inherited metabolic capabilities and the restrictions imposed by other organisms living nearby, dovetailing their active periods in order to reduce competitive costs. And in addition to elucidating temporal aspects of species' life-styles, studying diurnal and seasonal successions also enables naturalists to distinguish secular from seasonal successions.

A long tradition already exists in entomology for studying these cycles of activity because changes of kind in the activities of many insects exactly correspond to visibly distinct stages of their life-cycles. But few birdwatchers or botanists progress much beyond noting when the first swallows and primroses appear. Indeed, the ecological time-shares of many vertebrates and vascular plants remain little known. Amateur botanists, for instance, have never taken to studying seasonal succession, and the world still waits for them to take up White's suggestion (1890) that 'much instruction might be derived if a definite space ... were mapped

out, and a careful census taken of all the plants which spring up in it in the course of a season.' Indeed, unless naturalists curtail their wanderlust, they will never distinguish variations in time from variations in space and so elucidate temporal changes in the features and activities of organisms living in particular places. Meanwhile in professional ecology, diurnal and seasonal successions only attract sustained attention in limnology, because most plankton are similar in size, therefore easy to collect, and their spectacular variations in numbers can be analysed statistically.

For naturalists who regard grid-based recording of species' geographical occurrences as a last refuge of the intellectually destitute, using a Cartesian framework of biology to elucidate life-cycles and temporal aspects of species' life-styles may endow their days in the field with a more cerebral flavour. Perhaps field-guides and floras of the future will not only describe how species may be identified by their material features, and where they live (their environmental niches), but also their ecological niches or life-styles: when they can be found (diurnal and seasonal successions), together with other known aspects of their life-styles such as techniques of foraging and hunting, constituents of diet, and metabolic idiosyncrasies. In these ways naturalists may overcome their obsession with mapping distributions and move on to asking and answering why particular species live where they do, and not elsewhere.

So by further elucidating and familiarizing themselves with organisms' life-cycles and life-styles, naturalists may more accurately distinguish the effects of growth and seasonal succession from those of secular succession and evolution, just as biologists may better distinguish their causes. In particular, as genetic recombinations disperse and become isolated from each other when environmental conditions change, many of the evolutionary changes which biologists attribute to mutations may instead be attributable to sex and secular succession.

.....

Cuvier (1807) commented that 'the field naturalist passes through ... a great number of different areas, and is struck, one after the other, by a great number of interesting objects and living things. He observes them in their natural surroundings, in relation to their environment, and in the

full vigour of life and activity. But he can only give a few instants of time to each of them ... Thus his observations are fragmented and fleeting ... The sedentary naturalist, it is true, [relies on information which may be erroneous, and samples which may be damaged.] He cannot experience the great scenery of nature with the same vivid intensity as it can by those who witness it at first hand. A thousand little things escape him about the habits and customs of living things which would have struck him if he had been on the spot. [But] ... if the sedentary naturalist does not see nature in action, he can yet survey all the products spread before him ... He can examine them at his leisure ... [and] bring together the relevant facts from anywhere he needs to ... It is really only in his room that one can roam freely through nature ...'

This was a biologist speaking – a scientific philosopher, interested in Nature's big picture. Cuvier rightly regarded the description of species and investigation of the causes of organic diversity as indoor occupations. But there is more to understanding nature than contemplating it from a drawing room or laboratory, for we can elucidate diurnal, seasonal and secular successional aspects of species' ecological niches only by studying plants and animals in their native haunts. Natural history has moved on since Cuvier's time, and nowadays we not only study organisms' forms and structures, but also their activities and how these change with time as well as from place to place. Voltaire came closer than Cuvier to a naturalist's heart: "That is all very well", said Candide, in answer to the philosopher's interminable theorizing, "but we must go into the countryside, and work."

## BIBLIOGRAPHY

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- ALLEN, D.E. (1976). *The Naturalist in Britain. A Social History*. Allen Lane, London.
- APPEL, T.A. (1987). *The Cuvier–Geoffroy Debate. French Biology in the Decades before Darwin*. Oxford University Press, New York.
- BALZAC, H. (1842). Preface to *The Human Comedy* (trans. P. Morrison). In *The Nineteenth Century Novel*, pp. 140 ff. (ed. D. Kettle). Heinemann, 1972.
- BERTALANFFY, L. VON (1968). *General Systems Theory: Foundations, Development, Applications*. Penguin.
- CONDORCET, J.A.N. DE (1795). *Sketch for a historical picture of the progress of the human mind* (trans. J. Barraclough). Weidenfeld and Nicolson, London, 1955.
- CUVIER, G. (1807). *Analysis of a work of M. Humboldt entitled 'Tables of Nature'*, p. 6; quoted in Outram, D. (1984), pp. 62–63. *Georges Cuvier. Vocation, Science and Authority in Post-Revolutionary France*. Manchester.
- DARWIN, C.R. (1859). *On the Origin of Species by means of natural selection, or the preservation of favoured races in the struggle for life* (6th ed., 1872). John Murray, London.

- DESMOND, A. (1989). *The Politics of Evolution. Morphology, Medicine and Reform in Radical London*. University of Chicago Press, Chicago and London.
- DUREAU DE LA MALLE, A.J.C.A. (1825). Mémoire sur l'alternance ou sur ce problème: la succession alternative dans la reproduction des espèces végétales vivant en société, est-elle une loi générale de la nature? *Annales des Sciences Naturelles* 5, 353–381.
- ELIOT, G. (1884). *Essays and Leaves from a notebook* (2nd ed.). Edinburgh.
- FINDLEN, P. (1994). *Possessing Nature. Museums, Collecting, and Scientific Culture in Early Modern Italy*. University of California Press.
- FREUD, S. (1910). *Leonardo da Vinci and a memory of his childhood* (trans. The Hogarth Press and The Institute of Psychoanalysis, London, 1981).
- GARSTANG, W. (1951). *Larval forms and other zoological verses*. Oxford, Blackwell.
- HAECKEL, E. (1866). *General Morphology of Organisms*. Georg Reimer, Berlin. Edited and republished as *Natural History of Creation* (1868); 3rd edition translated by E. Ray Lankester. Kegan Paul, Trench & Co., London.
- HARDY, A.C. (1954). Escape from specialization. In *Evolution as a Process*, pp. 122–142 (eds. J.S. Huxley, A.C. Hardy & E.B. Ford). London, George Allen and Unwin.
- KIELMEYER, C.F. (1793). *Ueber der Verhältnisse der organischen Kräfte unter einander in der Reihe der verschiedenen Organisation*. Stuttgart. Reprinted in *Sudhoffs Archiv für Geschichte der Medizin und der Naturwissenschaften* 23 (1930), 247–265.
- KOESTLER, A. (1964). *The Act of Creation*, p. 227. London, Pan Books.
- LEONARDO DA VINCI (c. 1500). *The Notebooks of Leonardo da Vinci* (ed. I.R. Richter). *The World's Classics*, Oxford University Press, 1980.
- LYELL, C. (1830–1833). *Principles of Geology* (3 vols). London, J. Murray.
- MEDAWAR, P.B. (1955). Review. *Heredity* 9, 274–277.
- NIETZSCHE, F. (1886). *Beyond Good and Evil*. Penguin Classics.
- PLATO (c. 375 BC). *The Republic* (Part 9). Penguin Classics.
- POINCARÉ, H. (1908). *Science and Method* (trans. F. Maitland). Nelson, 1914.
- RAY, J. (1686). *Historia Plantarum*. Volume 1. London.
- SMITH, A. (1776). *The Wealth of Nations*. Strahan and Cadell, London.
- TAKHTAJAN, A.L. (1959). *Essays on the Evolutionary Morphology of Plants* (trans.) American Institute of Biological Science.
- THOMAS, K. (1983). *Man and the Natural World. Changing Attitudes in England 1500–1800*. Allen Lane.
- VALÉRY, P. (1895). Introduction to the Method of Leonardo da Vinci. From Leonardo, Poe, Mallarmé (trans. in *The Collected Works of Paul Valéry*, Volume 8, pp. 3–63, ed. J. Mathews). Routledge and Kegan Paul.
- VICO, G. (1744). *New Science* (3rd ed.) (trans. T. Bergin & M. Fisch, Cornell University Press, 1968) N2. 211–212; 816.
- WADDINGTON, C.H. (1968). The basic ideas of biology. In *Towards a Theoretical Biology. 1. Prolegomena*, pp. 1–41 (ed. C.H. Waddington). International Union of Biological Sciences Symposium, Edinburgh University Press.
- WADDINGTON, C.H. (1975). *The Evolution of an Evolutionist*. Edinburgh University Press.
- WAGNER, M. (1868). *The Darwinian Theory and the Law of the Migration of Organisms* (trans. J.L. Lair, London, 1873).
- WHITE, F.B. (1890). The Flora of river-shingles. *Scottish Naturalist* 4, 290–299.
- WHITE, L.A. (1959). *The Evolution of Culture. The development of civilization to the fall of Rome*. McGraw-Hill.

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