Chapter 3
Complexity: The Evolution of Identity and Diversity

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Introduction

Our aim here is to explore the consequences of complexity science for our understanding of the emergence and evolution of identity and diversity. The study of open physical systems, systems subject to flows of energy and matter, led to the understanding that structure and organization can form spontaneously as a result of small fluctuations tipping non-linear dynamical systems into different possible regimes of operation – called attractor basins. These ideas were first presented in the papers by Prigogine and co-workers (Nicolis and Prigogine 1977) – as Dissipative Structures – and by Haken and his collaborators (Haken 1977) – as Synergetics. Initially though, these ideas were about "driven systems" – systems that were subjected to flows of energy and matter that generated structures and organizations. However, the bringing together of these ideas with those already existing concerning biological evolution led to the idea of complex systems, that not only were subject to flows of energy and matter, but which also evolved so as to obtain, maintain and increase these flows. Ecologies and human social systems could therefore be seen as the result of evolutionary processes in which successive behavioural explorations occurred and those able to capture resources were retained in the system. The mathematics of what could invade such a system was presented in 1976 (Allen 1976) and the theories of evolutionary stable strategies (Maynard-Smith 1974, 1982) were of course a simpler, more closed version of this.

Evolution is important for our reflections on identity because it is the origin and the motor of emergent features and behaviours that express different identities. Non-linear dynamical systems, on the other hand, just "function". They may be capable of different regimes of operation, but essentially these are all present in the initial specification of the equations of the dynamical system. The real importance of "identities" only comes about in discussing how particular (temporary) dynamic systems emerge and exist for a time, before becoming unstable and giving way to

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some new system, with at least some new variables, relationships and emergent features. The underlying mechanisms of evolution were shown to involve micro-diversity within a system (Allen and McGlade 1987a) which drives an evolving, emergent system structure that is characterised by a changing level of structural diversity. This involves both the "selective" effects of interactions between species and the simultaneous mechanisms underlying micro-diversity that *discover* new "strategies" or "niches". In Darwinian thinking the micro-diversity that occurs is considered to be "random" and independent of the selection processes that follow, while in human innovation we like to think that there is intention, calculation and belief that may "channel" diversity into some narrower range.

Diversity is a measure of the number of qualitatively different types of entity present corresponding to individuals with different attributes. It may be that they share some dimensions, but differ on others. This is an important point because it refers to a fundamental issue for evolution – it concerns the qualitative changes that occur in systems and structures over time. This also introduces another important issue – that of multiple levels of description. In evolutionary systems, the internal nature of the interacting individual entities changes over time, as does the configuration of the interactions between these types, leading to a changing overall system performance within its environment. These internal characteristics would include individual values and ethics. This presents us with a view in which individuals are bundles of their internal components, the local community or organisations they form are bundles of these individual types, and ecosystems and larger structures they form are bundles of these local communities. The essential feature is that of the co-evolution of successive layers of interacting elements both horizontally and between levels. The performance and resilience of a community will depend, among other things, on the ethical values of the individuals that make it up. The diversity of the different levels of structure arises through these co-evolutionary processes that are in turn driven by the generation of micro-diversity – diversity at the level below. To illustrate this, let us consider the simplest possible example. Let us consider how a population evolves. It evolves if new behaviour both invades a population and also grows to a significant level in the system.

Complex Systems Modelling

What happens if we try to model an ecosystem using coupled equations of population dynamics? We can identify the different species present and find out who eats whom and calibrate the multiple plant/herbivore and predator/prey interactions. Now, once this is established, we can put the whole system of equations on a computer, and run it forward. What happens is shown in Fig. 3.1.

The model collapses down to a simple, much reduced structure. This is an astonishing result. It means that although the model was calibrated on what was happening at time $t = 0$ it diverged from reality as time moved forward. The real ecosystem stayed complex, and indeed continued to adapt and change with its real environment. But this shows us that *the mechanical representation of reality differs critically from that reality.*

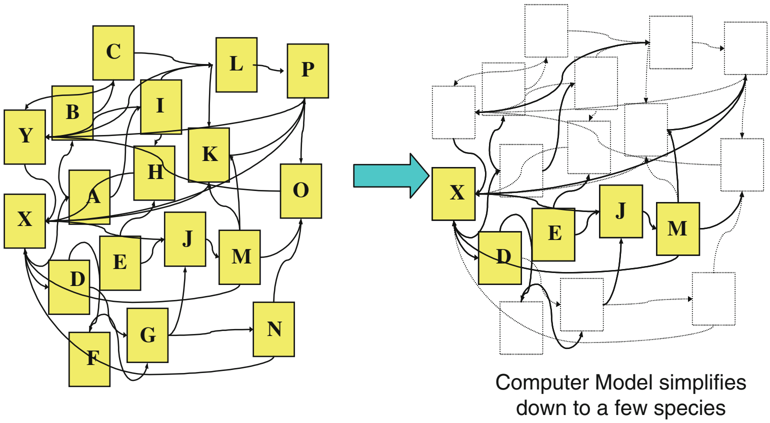

Fig. 3.1 A calibrated ecosystem represented by the population dynamics of its constituent species collapses when run forward in time

We can reveal the critical differences by carefully considering the assumptions that we made in formulating the model. In reality the interactions of a real ecosystem form parallel food chains, with cross connections and complications of course, but essentially with each level feeding on the lower one, some of these dying and others being eaten by the level above. The whole system of food chains loops back through death and micro-organisms that recycle all the carbon and minerals. The embodiment of these "food chains" is the identities of the different individuals that make up the populations. When we run the mechanical model – population dynamics with the fixed birth, death capture and escape rates that we have found on average in the real system (in analogy with chemical reaction rates), then the food chain with the highest performance simply eliminates all the others. In other words, selection between metabolic chains of *fixed identities* operates and this selects for the survival of only the highest performing chain. However, in reality this clearly does not occur! This therefore implies that a key property of a real ecosystem is the changing identities of its constituent agents! We need to understand how this is destroyed by the simplifying assumptions we make in building our "model" of the system.

This question has been examined in several papers (Allen and Ebeling 1983, Allen 1990, 1997) and they show that the evolutionary power of adaptive identities resides in the *internal diversity within the populations*. In reality, evolution leads to "populations" of sufficiently diverse individuals. Identities differ in age, size, strength, speed, colour, personality, and location etc. and this means that whenever a population, *X*, is being decreased by the action of some particular predator or environmental change, then the individuals that are most vulnerable will be the ones that disappear first. Because of this the parameter representing the average death rate will actually change its value as the distribution of identities within the population *X* increases the average "resistance". In other words, the whole system of populations has built in through the internal diversities of its individual identities, a *multiple set* *of self-regulatory processes that will automatically strengthen the weak, and weaken the strong.* In the same way that reaction diffusion systems in chemistry can create patterns in space and time, so in this more complex system, the dynamics will create patterns in the different dimensions of diversity that the populations inhabit. But neither we, nor the populations concerned may know what these dimensions are, the complex balance of heterogeneities changes as a result of evolutionary dynamics.

Reality emerges from micro-exploratory processes which we obscure whenever we deal in an aggregate variable X. Any description in terms of a "population" X automatically loses the different types of individual, the multiple identities present that actually allow the population to survive. An aggregate description cannot take into account the real interdependences between different types of agent or individual and a description, model, map or image of a complex, evolved system is only a temporary snapshot of its appearance.

A model constructed in terms of aggregate variables is like the famous painting of a pipe by Magritte called: *Ceci n'est pas une pipe* (This is not a pipe). We may look at the picture and recognize that it is a representation of a pipe, but it gives no idea of how the original came into existence, how it is affected by and affects other things, and certainly can never give the pleasure (or the danger) of smoking to anyone. Pedagogically it is interesting, since it enables us to recognise such objects as being pipes (while not being one) and we could certainly play wondrous academic games by considering different styles of "pipe", collecting images and discussing the materials, ancestry, technology that lay behind them. But just as the picture is not the pipe, the mathematical model of the ecosystem or of the economic system is NOT reality and neither are the statistics and databases of all possible measurements of input, output, throughput, or stock.

Any model is a particular, culturally based interpretive framework of some piece of reality that will always be incomplete. We have to face the fact that we can never fully create a representation of something that is fully that something, but may nevertheless hopefully allow some useful discussions or insights concerning it. That is really the hope of intelligence, since we can hope that by possessing language, and the capacity to label and discuss different objects and situations, then we can "do better" then if we couldn't. Of course, we may be wrong but what have we got to lose? In going from "reality" to some useful interpretation of that reality we actually make successive simplifying assumptions. This is shown in Fig. 3.2 which sets out the kind of models that result from a particular set of assumptions.

This succession of models arises from making successive, simplifying assumptions, and therefore models on the right are increasingly easy to understand and picture, but increasingly far from reality. *They also are shorn of their capacity for the participating identities to evolve – their real underlying exploratory, error-making processes.* The operation of a mechanical system may be easy to understand but that simplicity has assumed away the more complex sources of its ability to adapt and change. They become more like "descriptions" of the system at a particular moment, but do not contain the magic ingredient of micro-diversity that will really allow the system to undergo structural change and create a new, qualitatively different system, with some new variables and some emergent performance. The ability to adapt and change is still present in the "evolutionary" model that only makes assumptions 1

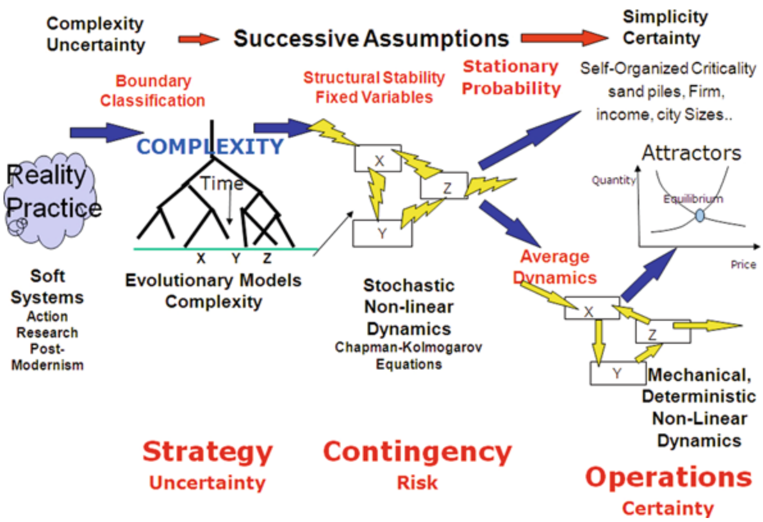

Fig. 3.2 This shows the results of successive simplifying assumptions that take us from a complex evolving system to its mechanical representation

and 2, but not those of average type and average behaviours. This therefore tells us that the evolutionary capacity is generated by the behaviours that are averaged by assumptions 3 and 4 – average types and average events – and therefore that organizations or individuals that can adapt and transform themselves do so as a result of the generation of micro-diversity and its interactions with micro-contextualities. This tells us the difference between a reality that is "becoming" and our simplified understanding of this that is merely "being" (Prigogine 1980).

Table 3.1. The different kinds of model that arise from successive assumptions

Number	Assumption made	Resulting model
1	Boundary assumed	Some local sense-making possible – no structure supposed
2	Classification assumed	Open-ended evolutionary models – Identities change over time
3	Average types	Probabilistic, non-linear equations – Identities are assumed fixed
4a	Stationarity	Self-organized criticality, equilibrium
4b	Average events	Deterministic, mechanical equations – Identities assumed fixed
5	Stationarity	Catastrophe theory, attractors, equilibrium

In reality, complex systems thinking offers us a new, integrative paradigm, in which we retain the fact of multiple subjectivities, and of differing perceptions and views, and indeed see this as part of the complexity, and a source of creative interaction and of innovation and change. The underlying paradox is that particular identities will each have their own "interpretive frameworks", generated by their own experiences and cultural identities, and will therefore not be able to understand others at all easily. But the behaviours of the differing individuals will interact through reality – and so actions based on any particular domain of knowledge, although seemingly rational and consistent, will necessarily be inadequate.

The reality of differing identities and different interpretive frameworks is one that we face in the real world. Managing organizations or making policies within social systems clearly presents real difficulties in dealing with these inherently incoherent views of what needs to be done, what is important and what should be aimed for.

We see a key framework that exists at the heart of complex systems thinking. The framework groups factors into three categories (Gillies 2001). These are:

- The values of *external* factors, which are not modelled as variables in the system. These reflect the environment of the system, and of course may be dependent on spatial conditions. Temperature, climate, soils, world prices, interest rates are possible examples of such factors.
- The effects of spatial arrangement, of juxtaposition and configuration, of the entities underlying the system, affecting self-organizing and autocatalytic effects.
- The values corresponding to the “performance” of the [underlying] entities, due to their *internal* characteristics like technology, level of knowledge or strategies.

These three levels are all coupled by interaction, and so changes that occur in any one will affect the other two. This in turn will affect the environment of the environment, the underlying entities of the underlying entities, and so on in an irreversible cascade outwards and inwards that makes everything essentially irreversible.

This new understanding of complex systems demonstrate the underlying difference between academic activities such as analysis and description and the domain of design, action or intervention that concerns real life, and practitioners.

Micro-Diversity-Evolving Identities

The dialogue between population dynamics – the simple reduced model of an ecosystem – and mutations or innovations, is particularly interesting in that it gives rise to what is usually referred to as evolutionary ecology. This has been presented in a recent article (Allen et al. 2006) and so we shall not go into too much detail here.

Evolution of Populations

The simplest possible equation for an ecosystem corresponds to a single species growing according to the logistic equation,

$$\frac{dx}{dt} = bx\left(1 - \frac{x}{N}\right) - mx \tag{3.1}$$

This equation, describing the growth of a species x in a system with limited resources has a stable, stationary state, $x^0 = N\,(1 - m/b)$. The average "identity" of the different individuals is such as to produce parameters that are, on average, b, m and N.

But what new population type could invade the stationary state of Eq. (3.1)? This focuses on the stability of the "identity" of x, as some deviant types may try to invade. Let us consider the arrival in the system of a "mutant", x', that is different from x. For example, x' competes with x to an extent β for the limiting resource N ($0 < \beta < 1$). If β equals 1, then we have the same essential identity as x, but if it is less than 1, then it must have features that distinguish it from x, and therefore constitute a different identity. The mutant is characterized by some other birth rate b' and death rate m'. We shall suppose that after being subjected to some initially stochastic events, it has managed to survive and to become sufficiently numerous to be able to speak of a "density" (albeit very low) of mutants. The system equations become:

$$\begin{aligned} \frac{dx}{dt} &= bx\left(1 - \frac{(x + \beta x')}{N}\right) - mx \\ \frac{dx'}{dt} &= b'x'\left(1 - \frac{(x' + \beta x)}{N}\right) - m'x' \end{aligned} . \tag{3.2}$$

What are the values of $b^\bullet$, $m^\bullet$ and β such that x' can invade the system. This question is decided by testing the stability of the pre-existing state, $x = N\,(1 - m/b)$; $x' = 0$. If it is stable, then x' cannot invade the system. If it is unstable, invasion can proceed.

A simple stability analysis shows that the condition for x' to invade is,

$$N'(1 - m'/b') > \beta(N(1 - m/b)) \tag{3.3}$$

When this condition is fulfilled, x' will grow.

Two cases arise. If the mutation x' were in total competition with x, then $\beta = 1$, $x^\bullet$ has essentially the same identity as x, and the condition becomes:

$$N'(1 - m'/b') > N(1 - m/b) \tag{3.4}$$

Hence, as a result of random mutations, evolution within a given "niche" (identity) can only lead to increased "exploitation", or increasingly efficient use of the resources. The important point in this case is that, the condition that allows x' to grow also ensures that x must decrease and disappear, as portrayed in Fig. 3.3.

When overlap is not total, $\beta < 1$, invasion is easier, since the value of $N'(1 - m'/b')$ need not be as high. What we shall observe, therefore, in a system with limited resources is that over a long period of time an initially empty resource spectrum will gradually be *filled* by different populations, each adapted to a certain range of resources. Also, within any particular range or type of resource the efficiency

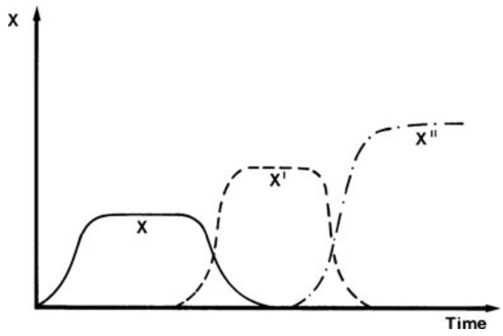

Fig. 3.3 Within the same "niche", we find successive replacement by individuals with more "effective" identities

of exploitation will increase irreversibly. This result can be extended to situations where genetics are explicitly considered, but these slightly more complicated equations do not lead to a different qualitative result.

This approach can be generalized and applied to many different kinds of ecological system, Allen (1976) and Allen et al. (2006). It captures the condition that limits which new identities and behaviours can actually invade a system successfully. One particularly interesting application is to consider what total population diversity and range of different identities can occupy a given resource spectrum. We first calculate what degree of specialisation will evolve in a particular environment, and then how much separation there will be between the niches of different populations. We will then be able to predict how many species will occupy a mature evolved ecosystem with a particular spectrum of resources. We suppose a resource base of length L and density c. May already showed (1973) that the separation between two species should be proportional to the amount of environmental fluctuation. However, we have shown (Allen 1985) how evolution would lead to the "width" occupied by a species, so it is possible to combine our results with those of May (1973) to obtain an expression for the expected morphological diversity (in a single level, simple, highly artificial example, of course). If the number of species is n, and their "niche" separation d, then we should find that, $d/w = \varepsilon \mid \sigma^2 \mid$, where σ reflects environmental variability, since $n = L/d$ then

$$n = \frac{L}{\varepsilon\sigma^2 w_s} \qquad \textit{That is } nw_s = \frac{L}{\varepsilon\sigma^2} \tag{3.5}$$

Some partial confirmation of this relationship has been obtained. It concerns "Darwin's Finches" which inhabit the Galapagos Islands. As is well known, the Islands are home to some 14 species of finch, which are generally not found elsewhere (Fig. 3.5).

Large islands carry greater numbers of species types, and total characteristic diversity than small islands. Although the exact make-up of the finch community cannot be predicted, the total diversity supported by a given resource base can be.

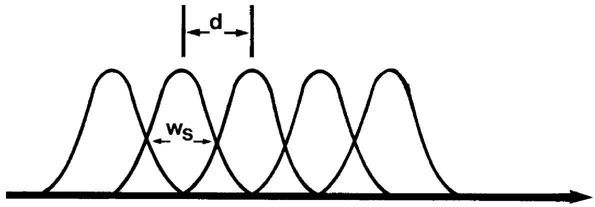

Fig. 3.4 A resource spectrum is supposed occupied by different populations, each of width, *w*. and separated by distance, *d*

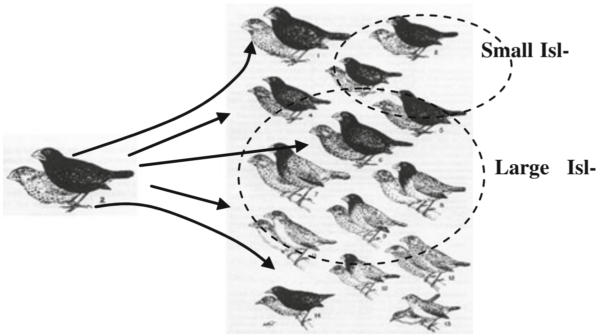

Fig. 3.5 The finches of the Galapagos. Male and female of each species. The 3-D visualizations were made by Jack Corliss, Mike Lesser and John Dorban at the Goddard Flight center, NASA

We can link resource volume, environmental fluctuation, and morphological diversity and "predict" the volume of identities/niches available to different populations, assuming the structural stability of the overall ecology. In other words, evolution leads to a given amount of "coherent" diversity of the identities of the constituent populations. But, the motor that drives this evolution of identities is actually that of micro-diversity generation – diversity produced at the level below that of the ecosystem. This tells us something quite fundamental:

- Identities evolve over time as part of the system and therefore are mutually interdependent.
- The heterogeneity or homogeneity of different identities play a role in the resilience, creativity and survival of the populations present.

We can run a simulation in an imaginary two-dimensional character space in which the exploratory behaviour of new identities "diffuses" outwards from any existing population. When populations are close, then they are "competing" with the original types, but as they move further away the differences mean that they no longer compete. We have made simulations with these simple rules in the behaviour, and found that such a system generates an evolutionary tree entirely spontaneously.

In some ways a supply chain is an example where the different nodes of expertise and knowledge work together to create a complex product that commands resources

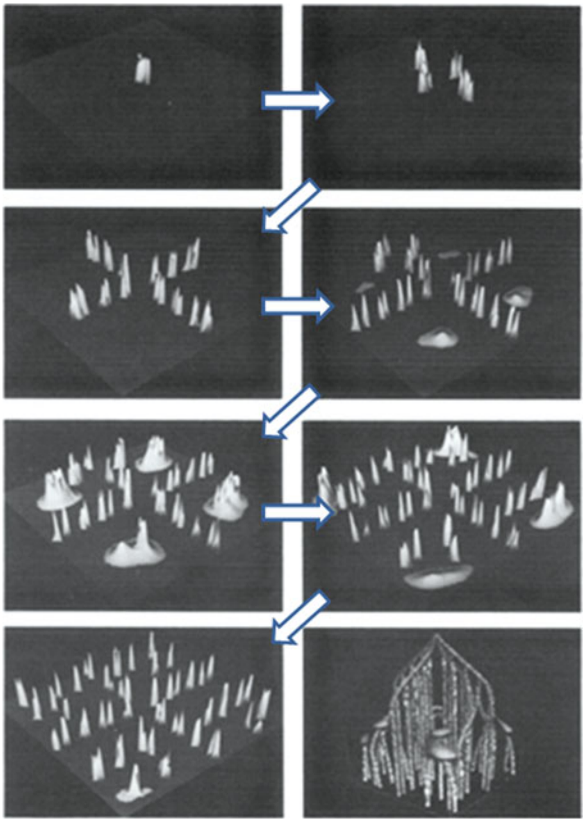

Fig. 3.6 In "possibility space", an initially pure identity will diffuse outwards and differential success will provide "selection"

from the environment. The division of labour in societies is clearly an example of interlocking, synergetic work identities that can be spectacularly successful. Of course, other factors are also required for sustainability. For example the different players must feel some justice in the partition of rewards, considering the effort and skills required. In the longer term, also, the effects of any of the specialized activities on the social or physical environment must be considered to be reasonable by the collectivity.

This work shows us how we can understand how identities and systems of interacting identities evolve and change over time, and how complexity shows us a generic mechanism that underlies all such phenomena.

Complexity of Individual and Collective Identity

Some time ago some studies and models of fishing behaviour in the Canadian Atlantic fisheries showed that sustainable behaviour did not result from the most efficient exploitation of current knowledge. Fishing fleets that were given behaviours based on strong economic rationality did not do well over time, even though at each and every moment, this is the most successful short term strategy. The point is that this strong economic rationality applies to the moment, whereas sustainability is about the longer term. Exploiting currently known knowledge does not consider the question of how one can generate new knowledge. Over the longer term, the exploitation of the initial knowledge is very minor compared to the need to be able to discover, assess and then exploit new knowledge. Exploiting knowledge of existing fish stocks decimates them and so this is why it is absolutely vital to have behaviour that can discover new stocks.

This idea is completely fundamental. All evolved systems need to accomplish two almost opposite tasks if they are persist over a long time. First they must develop an internal structure of interacting identities that can together do something currently that allows them to pump resources in to maintain and grow their structure. Secondly, however, they must be capable of creating and transforming these identities, and what they do, in order to deal with a changing world. As we saw above in much of biological evolution ecological communities achieve this normally as a result of the occurrence of mutation and natural variation through which individuals can explore the pay-offs for new identities. Because of the differential selection of these behaviours, fitness within a given niche improves, and new niches are opened up and explored.

In human systems however, our reason can suppress these natural explorations in order to focus and amplify the currently most successful behaviours. In other words, we can "lock-in" to a particular circumstance and through the creation of an extremely efficient system of exploitation of current resources can suppress the natural adaptive capacity of the system that would be more pluralistic and heterogeneous. In some recent work by McGlade et al. (2005), a study has been made of the decline of coal mining and the associated communities in South Yorkshire. It demonstrated essentially how the geography of coal deposits, and the social evolution of the mining communities, mining towns evolved to become essentially "mining machines" where people's identities and roles were all aimed at this single overall activity. This operated and evolved successfully for at least four generations, but when the demand for coal from South Yorkshire inevitably fell, the communities that were affected had no response other than to fight for the continuation of its coal mining. The study documents the numerous ways in which the social, educational, family and institutional structures were all based on continuing coal mining and had no alternatives available. The result was a social disaster that is taking decades to resolve itself. Since economic transformation was accomplished with far greater success by longer term policies and carefully planned actions in both Germany and the Netherlands, it is clear that it is important to recognize these issues and to develop policies that are appropriate to the task.

The development of the multiple and diverse skills, social relationships and ethical values that characterized mining communities was a remarkable story of growing efficiency and technological advance, with team working and interdependence that gave rise to a social experience much more intense than that experienced by suburban dwellers. However, the fixity of the identities and roles, and the unity in defence of the way of life is what led to the lack of adaptability and failure to "move on" to new things. In comparison, someone from suburban London, for example, never knew a community, and never had to conform to any particular career or role paths laid down by others. All was possible, all was open and nothing was really forbidden. Obviously, there was a general feeling on the part of parents that they hoped their children would "get on", but this was a relatively vague concept and could be influenced by emerging opportunities and influences that were experienced at school.

This rather soulless society gave rise to a very adaptable, open post-war generation that could embrace whatever careers were on offer, and through this could build a complex and diverse economic system which it is difficult to characterize, other than by "post-industrial". Clearly, there were also no real selection operating for ethical values providing some "community performance", and so over time social solidarity, and shared values have slipped away. Definition by what something is NOT is an interesting idea, and shows that really we still do not really know what is driving our current economic capacities, and how they interlock and co-evolve. Our world is really like the Chesapeake Bay ecology of Fig. 3.1, where we can classify existing elements, collect all kinds of data concerning their connection, build "models" that are essentially accounting equations that track flows, but we cannot capture the essential creative forces that drive innovations and adaptation forward from within the different levels of the system. One may even surmise that the more clearly one can understand the functioning of a system, the more that system is fossilized and non-adaptive, since the adaptive capacity springs from what is not clear.

Clearly the ethical values of bankers and traders was such that their own short term profit drove their decision-making and eventually crashed the whole international financial system of which they were a part! As we said above, community fitness and resilience is a function of the collective effects of individual characteristics – such as ethical values. In fact regulation and anti-monopoly laws have to try to provide the restraints that internal ethical values clearly do not.

Economic and Organizational Identities

The above is also true for the companies and firms that make up an economy. They too must both create an identity, an identifiable product and brand that some customers want, but they must also be capable of evolving and co-evolving it with their competitors and their customers within a changing technological and social environment. It is the precise "recipe" for this double game that is difficult to specify. If it were easy, then the recipe would be a mechanical set of rules and adaptation and learning would just be part of the standard game. But in reality organizational change is driven more real than the structures that appear to be present at any particular moment (Murray et al. 2002).

So an economic market is not a set of interacting firms and their products, and a set of customers who all make decisions that rapidly clear the market. The whole point is that neither suppliers nor customers know what price is reasonable for which product, and they use the economic market to learn about pricing strategies and products that lead sufficient customers to buy the goods, so that the production can grow and then be maintained. But this takes some time, and during that time innovations will occur, and the use of the product by customers will produce new potential demands for further innovations, so producing a market evolution. These evolutionary market models have been described elsewhere (Allen et al. 2007). Each model run, having a different sequence of events leads to different market structure, since there are path dependent learning processes involved. The non-linearities produced by fixed and variable costs are quite enough to make decisions concerning profit margin and quality made in the early stages to mark irreversibly the outcome. Each model run is like a particular run of history, and what matters is the ability of participating agents to learn sufficiently from whatever situation they are faced with. Just as Darwin's finches co-evolved to a stable pattern on different Galapagos Islands, so firms must adapt their profit margin and quality so that a stable co-existence can emerge in the market place.

By continuously adding the profits of all the firms, and the costs of bankruptcy, we can get a continuous trajectory for the total profitability of the market place as a whole. These market simulations show that depending on unpredictable events, market evolution can be quite different, with the spread in the trajectories demonstrating the importance of luck. The model shows that if firms adopt different learning rules (random, imitation of winner, hill-climbing, diverse) the average gain and spread of the trajectories can be affected. Darwinian, random learning is least effective, and learning from marginal changes in profit margin and quality is the most effective.

Similarly, based on the transfer of ideas from biology to industrial evolution.[43] We have considered the evolution of the internal, organizational form of firms and shown how the different possible bundles of working practice can form particular clusters of synergetic behaviour, with characteristics of performance that can co-exist with other organizational forms. This work was described in several recent papers (Allen et al. 2005). Fifty three different working practices were defined as the underlying possible components of different organizational forms in the history of the automobile sector.

In Fig. 3.7a, the model allows us to define a definitive branching point where the structures on either side of the divide differ by 17 conflicting practices. Once a firm has engaged down one path it will not be able to change its mind and take the other. This shows the importance of these ideas for strategy. It also shows us the complex interplay of diversity, identity and inter-connectedness, whereby an industry evolves different organizational forms (identities) as a result of internal micro-diversity as new practices and traits are launched and tested, and either accepted or rejected by the organization in which they are tried out. If they are rejected then they do not

[43] McCarthy (1995), McCarthy et al. (1997), and McKelvey (1982, 1994).

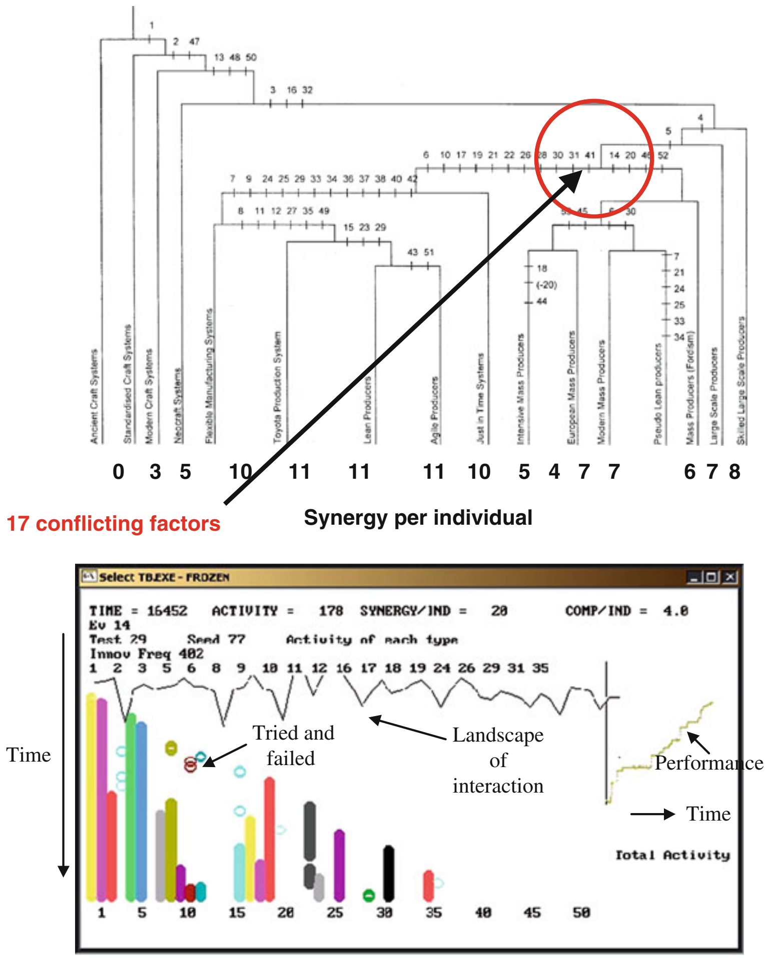

Fig. 3.7 (**a**) The Industry: 16 organizational identities emerge as different histories create a branching evolutionary tree of different bundles of practice. (**b**) The firm: An individual firm traces its own path through the tree

affect greatly what can currently invade the structure. If they are accepted however, then the new "composite" structure will have different susceptibilities to invasion than before. This means that different organizations trace out different pathways through an expanding tree of possible structures that collectively make up the industry. Once again, the micro-diversity of working practices leads to the emergence of co-evolving organizational forms and identities again reminiscent of Darwin's finches. In different markets, different combinations of organizational forms may be appropriate, just as on different Galapagos Islands different combinations of finches can co-exist.

Conclusions

Our reflections concerning how complex systems of co-evolving agents with underlying micro-diversity and idiosyncrasy, then we *automatically* obtain the emergence of successive non-linear, dynamical systems. These "structural attractors" are temporary, emergent dynamical systems of limited dimensions, which approximately possess the property of "self-organized" criticality from among the much larger space of possibilities. These are complex systems of interdependent behaviours whose attributes are on the whole synergetic. They correspond to the emergence of hypercycles in the work of Eigen and Schuster (1979), but whereas the hypercycle is thought of only as a functional entity, in reality structural attractors have emergent collective attributes and dimensions. This is its identity. The structural attractor (or complex system) that emerges, results from the particular history of search and accident that has occurred and is characteristic of the particular patterns of positive and negative interactions of the components that comprise it. In other words, a structural attractor is the emergence of a set of interacting factors that have mutually supportive, complementary attributes.

The identity of an individual is related to the interpretative framework that they have developed with which to view and respond to events and experiences in the world. This very simple idea is shown in Fig. 3.8, where actions are guided by the interpretive framework that includes both beliefs about how the system works and what it is composed of, and of the values or goals that are to be respected or aimed for. Both of these are therefore the fruit of the family and cultural experiences of the individual concerned as well as of any fundamental genetic identity as well.

When events appear to support the current "understanding" and values of the individual then there is no need to change anything. But when events do not unfold as expected, or consequences appear to clash with values and goals, the individual

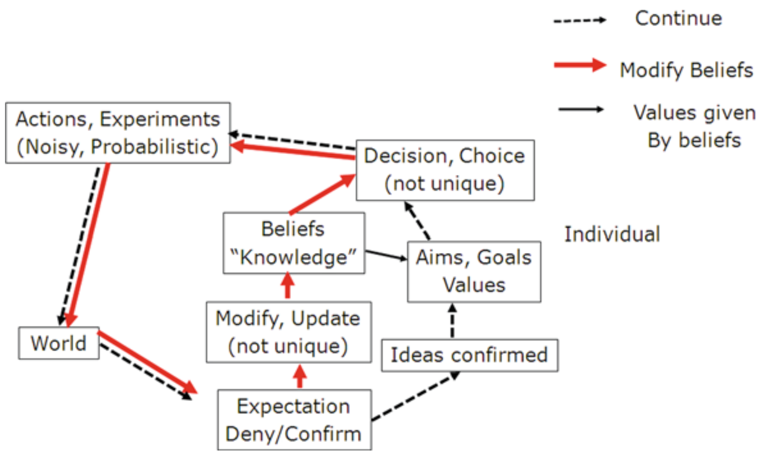

Fig. 3.8 Identity is really about the internal interpretive frameworks developed by individuals. Diversity arises because there is no unique, scientific or correct way to modify a framework in the light of events

will attempt to "up-date" and modify the interpretive framework – their model of the world.

The key point here is that there is no unique way of interpreting the "meaning" of new events or experiences into the existing view, and so individuals will tend to do it in different ways. There may be approximate cultural commonalities, but nevertheless there is no scientifically "correct" way to do this and so inevitably individuals will inherently diverge in their interpretations. This does not mean that any interpretation (or model) of the world is as good as any other, because experience will demonstrate that some views are clearly at variance with what happens. However, this still leaves a wide range of interpretations that are possible and still no unique way of up-dating them in the light of some new confounding experience. It also points to the idea that we should really be looking at our own actions as "experiments" that everyday test our understanding of the way things work – and what things "really" are. Clearly, given this lack of authority, and the difficulty of choosing one's own new beliefs, many may simply adopt similar views to a preferred group, and simply mimic their responses without in reality understanding the basis of these. Figure 3.8 shows us that complexity is about how there is a co-evolution between ontology, epistemology and axiology – the breadth of the reality we perceive, the experiments we perform that test its coherence, and the values and goals that underpin our existence.

We see that the evolution of complex systems leads naturally to:

- Diffusion in character space leading to the emergence of co-evolved identities that are either synergetic or at worst can co-exist together. Instead of a homogeneous system, characterised by intense internal competition and low synergy, evolution driven by the generation of micro-diversity of identities leads to the emergence of heterogeneous structures with much higher performance, and reduced internal competition.
- Overall it leads to the evolution of a complex, a "community" of agents whose activities, whatever they are, have effects that feed back positively on themselves and the others present. It is an emergent "team" or "community" in which positive interactions are greater than the negative ones.
- Such systems represent the assemblage of a reduced set of activities from all those possible in principle. These will be the particular ones that history and its accompanying accidents. Happen to have led to, but will correspond to some degree of synergy and reduced conflicts If all possible components were put together then the result would be a confusion and conflict of competing structures, whereas complex systems are really particular bundles of not mutually incompatible components. In classical dynamics an attractor refers to the long-term trajectory traced by the given set of variables. Here, we call a complex system that has some temporary persistence a structural attractor, characterized by the *emergence* of variables, dimensions and attribute sets that not only coexist but actually are synergetic.
- Sustainability results from the ability of systems to move from one structural attractor to another. It will be system that exhibits temporary stability for a time

and then is able to move on to a new form as the environment changes again. This discovery of different and multiple forms of co-operative and synergetic identities with complementary capacities, reduces internal competition. In other words, the free evolution of the different identities, each seeking their own way forward, leads to a system that is more co-operative than competitive.

The most important point really is the generic nature of the model presented above. The same ideas explain the evolution and co-evolution of Darwin's Finches, of economic markets, of organizational forms and of social entities such as our South Yorkshire miners.

A successful organism, product, organisation or social group is one which can discover successful "bundles" of component identities. These must possess emergent attributes and capabilities that assure the resources for its production and maintenance in the present. However, they must be capable of continuing their messy exploration of possible identities that allows them to find new, more adapted structures to the changing environment in which they live. The structural evolution of complex systems is driven by explorations and perturbations that test the stability of the existing attractor, either leaving it intact or evolving towards a new structural attractor involving some new "concepts" and emergent properties.

We can also draw some conclusions about the level of "cognition" required by organisms, individuals, firms/agents to survive in evolving structures. Broadly speaking we see that almost no knowledge is required for "agents" to generate successful heterogeneous complexes. Providing that there is micro-diversity among the agents, even with an entirely "random" basis, eventually the evolutionary system will discover a structure that is stable. In the economic market example, we know that purely random explorations, with no consideration of what seems to work, and what the successful directions seem to be can lead to a very slow rate of improvement of performance. In the further simulations, slightly more sophisticated learning methods are supposed in which either successful competitors are imitated, or trials are conducted to allow "hill-climbing" behaviour of the profit slope, but all of these require only very limited cognitive power. The "intelligence" that apparently underlies a coherent market structure lies not within the agents/firms that participate within it, but in the non-linearities inherent in the economic interactions that are present – the economies of scale, the fixed and variable costs, the degree of discrimination of potential customers. In reality collective intelligence is what emerges through evolution and this really requires very little cognitive power on the part of the participating individuals.

In the second example of structural evolution at the level of the internal structure of competing agents/firms, we wee that it is the very ignorance of actual consequences of adding one practice rather than another that generates diversity of the different agents/firms, and allows a successful evolution of the industry. The evolutionary models described above show us the importance of the multi-level nature of socio-economic systems. Individuals with characteristic and developing skills and particularities form groups within companies, generating specific capabilities and also particular receptivities for possible future changes. The products and services that emerge from this are perceived by a segmented and heterogeneous population of potential consumers, who are attracted by the qualities of a particular product or service and the low price at which it is offered. This results in a market share and in changing volumes of activity for different firms. When volume increases, economies of scale occur and allow further price decreases and greater attractiveness for potential customers. However, debts can be cleared quicker if higher prices are practiced, and since there is an interest rate in the model, paying off debt is also a way of reducing costs.

The important result from these multi-agent, complex systems simulations discussed above is that instead of showing us *the* optimal strategy for an individual, agent or firm, they tell us that there is no such thing. What will work for one person or company depends on the strategies being played by the others. The overall lesson is that it is better to be playing within a diverse ecology than in a limited, potentially vulnerable one. So, having a unique identity may seem “risky”, but it is better than simply packing into the same strategy as others. Coupled with having a clear individual identity, it is an advantage to “learn”. So, exploring the landscape sufficiently by doing experiments and interacting with it may enable faster “learning” than otherwise, but this will only be true if the “feedback” of the environment can be interpreted. In many situations involving highly connected individuals within organizations the feedback of experimental behaviour simply cannot be read and so learning is in reality impossible. In these cases, it may be necessary to develop an operational model in order to be able to calculate the collective outcome of particular combinations of behaviour of the multiple agents (Datta et al. 2007).

The new theoretical framework of evolutionary complex systems is about the emergent and creative co-evolution of identity and diversity at different levels of the system. We have a dialogue between explorations of possible futures at one level, and the unpredictable effects of this both at the level below and the level above. There is a dialogue between the “trade-offs” or “non-linearities” affected inside and outside the particular level of exploration. But it is also true that all levels are exploring. Unless there is an imposition of rigid homogeneity up and down the levels of the system, there will necessarily be behavioural explorations due to internal diversity. In this way, multi-level systems are precisely the structures that can “shield” the lower levels from instantaneous selection, and allow an exploratory drift to occur, that can generate enough diversity to eventually DISCOVER a new behaviour that will grow. Without the multiple levels, selection would act instantly, and there would be no chance to build up significant deviations from the previous behaviour.

It supports the view of evolutionary economics driven by “restless capitalism” (Metcalfe 1998). Of course, many decisions will tend to reflect the short-term positive performance of something with respect to the dimensions of which we are aware, but obviously, in a complex system, there will be all kinds of less obvious factors that are perhaps adversely affected. In other words, what we choose to do is dependent on "what we are measuring", and so the system changes reflect our limited understanding of what will actually affect us. This is because our actions are based on our limited understanding and knowledge of the complex systems we inhabit. And their evolution therefore bears the imprints of our particular patterns of ignorance. So, we may grab economic gain, by pushing "costs" into the "externalities", or we may seek rapid satisfaction from consuming some product that actually harms us, or our community, or our region, or the ozone etc. over the longer term.

This chapter shows us how identities, including ethical values, are created and co-evolve in an on-going evolutionary process, where it is the selection operated by the collective interactions that feeds back on individual experiments. Because of this, we cannot really ever fully understand why things got to be as they are, and in what precise way they may evolve. We cannot understand what exactly created the micro-diversity underlying Chesapeake Bay, an evolving economic market, an evolving organizational form or industry, or a social group such as a mining town. But can see that all these phenomena obey the same kind of behaviour – that of evolving complex systems. We need to allow ourselves to be "evolvers" – to both encourage and allow exploration both of behaviour and of values - and to pick up on what works and what doesn't. Instead of fossilizing our identity, skills, role or knowledge, we need to keep pushing back its limits, trying new things and learning things even though we cannot say ahead of time what the exact purpose will be. Of course, we may need to be particularly prudent about experimenting with ethical values but in fact the experiments are occurring in any case. Perhaps an open recognition and discussion of such matters is important and ultimately we may need to decide whether survival is the ultimate measure of such things or whether there should be "absolute values" that must never be questioned, even though survival may be jeopardized. The future problems of populations not being aligned to the food production and water consumption potential of the planet will probably test out these issues fairly soon.

Fortune favours the brave – those that are prepared to move on, to change and to adapt, and since the future is not known then we cannot prescribe the "best" things to learn. However, by exploring our own diversity, and building upon it we create a richer set of possibilities on which the collective system can thrive, and providing that multiple connections are tried out, then there are multiple possible new synergetic bundles that can emerge. So, the fact of uncertainty about the future, and the impossibility of knowing exactly how our current interpretive framework should be up-dated, leads naturally to a divergent, branching evolution of possible identities and diversities, which then compete and co-operate leading to the selection of compatible sub-sets, creating multiple possible futures, some of which at least will survive. The question is whether ethical values are what evolution creates in surviving structures or whether we can consider some ethical values as absolute, and hope that evolution will still allow us to survive. Complexity poses this question but does not answer it.

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