# Chapter 2
# Emergent Systems: Nested, Fast, and Slow

*What matters is that the movement and fate of the parts from that time onward, once a new whole is formed, are thereafter governed by entirely new macro-properties and laws that previously did not exist, because they are properties of the new configuration ...*

Sperry 1986, p. 267

Where do these game-changing qualities, such as a new coffee shop culture or the attraction of engraved padlocks, come from? As indicated above, I suspect that such qualities are due to properties that can only be found in complex systems, but not in analytical or statistical ones. These properties are not (yet) usually considered when decisions are made in complex systems. I claim that the available approaches cannot predict *new* qualities, which, I argue, are the true game changers in complex systems. It is the core concern of this chapter to uncover this property of complex systems.

Is it, in principle, possible to know what the future may bring for complex systems, i.e., what may interfere with our plans? Or do we simply have to deal with novelty that is, in principle, unpredictable? Would such novelty arrive out of the blue, or could it at least be anticipated as the result of contemplation—or even of a subtle feeling? Considering the often seemingly stable order of urban or other complex systems, how may novelty exert any significant influence at all?

In this chapter, I aim to provide a first understanding of complex systems as *Emergent Nested Systems*. In brief, I will claim that complex systems are emergent and that a relatively faster system is always enclosed by a relatively slower one. This chapter and the following two chapters will present a largely theoretical contribution; however, here and there, I will exemplify some points by referencing urban systems, or systems that can be found in cities. I will exemplify the applicability of my theoretical contribution in Chap. 6.

Developing this contribution would not have been possible for me without the ground prepared by prior works of many remarkable scholars. Among the works cited throughout this chapter, I would like to highlight the first chapter in *The Self And Its Brain* by Popper (1977), and "The Architecture of Complexity," an article by Simon (1962); these are very fruitful resources concerning "the admittedly vague idea of emergent evolution" (Popper 1977, p. 16).



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In the former mentioned work, Karl Popper introduced his propensity theory (first published in Popper 1959) on the probabilities of *single cases* into the wider context of emergence, e.g., the emergence of life, consciousness, and "creativity…which…we find in man" (Popper 1977, pp. 15ff.). In the same chapter, he also introduces levels of emergence in nature, and furthermore, he suggests that there is both outward and inward influence acting between the levels. "Each level is open to causal influences coming from lower and from higher levels" (Ibid., p. 35). The blend of propensity theory with notions of emergence is what makes Popper's ideas the point of departure for my work. Also, his merely-sketched theory presents the possibility to re-conceptualize—in light of the recent developments in system and complexity sciences—a theory of emergence.

In the latter mentioned work, Herbert Simon attributed high-frequency dynamics to enclosed systems and low-frequency dynamics to enclosing systems. However, Simon did not, at least to my knowledge, suggest any relation between emergence, nestedness, and fast and slow systems.

Many other scientists, who have influenced the development of my theoretical contribution, have been working along the same, or complementary, lines. These scientists notably—but certainly not exclusively—include Herman Haken (e. g.1977, 1981, and 2012), Christopher Alexander (2002a, 2002b, 2004, and 2005), and Christian Fuchs and Wolfgang Hofkirchner (e.g., 2005).[1] It should not go unmentioned that many other scholars have worked on theories of emergence over the past 100 years—from the British emergentists (e.g., Samuel Alexander, Charles Dunbar Broad, and Conway Lloyd Morgan, cf. Stephan 1999) to more modern proponents, such as Roger Walcott Sperry and Donald Thomas Campbell (cited in, e.g., Popper 1977) and the contemporary American emergentists, such as Sawyer (2005) and Deacon (2011).

However, none of the scientists mentioned in the last paragraph seem to have been aware of the high- versus low-frequency dynamics mentioned by Simon—an idea which plays a key role in my work.

**Structure of This Chapter**

The structure of this chapter can be understood along three key themes: unknown unknowns, propensities and emergent qualities, and properties of nested systems, especially the relation between relatively fast and relatively slow systems.

At first, I will suggest that *nested* systems emerge out of propensities, i.e., inherent dispositions of *unique situations*. This means that the emergence of a system is not under the control of anyone, and that it cannot be predicted before it starts to exist (Sects. 2.1 and 2.2). This, of course, has consequences for the value of *comparative* case studies; more about this in Chap. 5.

The notion of *emergence* is certainly the most intriguing one here. I will argue that emergence always involves a *qualitative leap*, i.e., a new quality beyond what could have been imagined, based on known qualities and the knowledge of the situation

[1] Although Alexander is approaching complex systems from a slightly different point of view, I'm convinced that he is working on elucidating the very same quality. What he calls life, the quality that creates and is bound by centers, is what I describe here as emergent quality—being enclosed as a center and enclosing other centers.

it appeared from. There are qualities which we have no ability to know, predict, or imagine until they start existing in this world. I.e., how could life have been imagined in a world without life, and how could a city have been imagined in a world with only scattered farmhouses?

In Sect. 2.2, I will argue that the ever-new emergence of systems actually leads to a *nested* arrangement (Sect. 2.3.1). In nested arrangements, the emerged systems are guiding the systems that previously existed by means of *new rules* (Sect. 2.3). I will explain in Sect. 2.4 how the nested systems always exhibit faster *dynamics* than the nesting ones. In a nested arrangement, the emerged slower systems guide the fast systems' activities, while the fast systems might, in turn, indirectly change the guiding rules—a relation that I consider to be most crucial for the understanding of complex systems.

The bottom line with regard to decision-making in complex systems might appear as trivial as this: Plans don't work because situations change. The entire story, however, is not as simple as this sounds.

## 2.1 What Do We Not Know that We Don't Know?

Man is continuously making decisions based on limited, imperfect knowledge. On one hand, this is due to individual limitations of knowledge, since "knowledge…[is] not given to anyone in its totality" (Hayek 1945, p. 520).[2] On the other hand, there is,

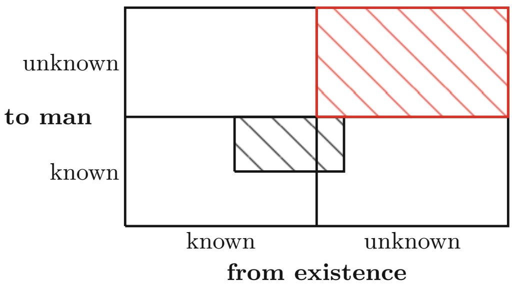


**Fig. 2.1** The four realms of (un)knowledge. The knowledge of the individual (*dark hatched area*) excludes unknown knowns. It is furthermore limited to the individual's subset of known knowns, i.e., the knowledge about what exists in the world, and known unknowns, i.e., the knowledge that some situations in the future cannot be known, e.g., the time and strength of the next earthquake. Like known unknowns, which may not be known by anything in the universe except man, unknown unknowns do not yet exist in the universe. Unknown unknowns involve objective novelty and, hence, they cannot be known by man (*red hatched area*)

[2]Hayek draws on the problem of complex situations. To Hayek, complex situations depend on such a large amount of mutually dependent variables that it is practically impossible for man to find out how a situation came into existence (see, e.g., Hayek 1964, pp. 343ff. and pp. 348ff.).

at any given time, knowledge which cannot be possessed by anybody—knowledge of the future.

Everything outside of what is known to the individual can be considered as the individual's "unknowledge" (Shackle 1974, p. 4). This individual unknowledge can be reduced by gathering other individuals with complementary knowledge (known knowns) and by acquiring knowledge through research (making known knowns from unknown knowns). For example, bacteria were unknown knowns—known to the universe (they existed in), but unknown to men—before they were *discovered* by van Leeuwenhoek in 1676 and, hence, became known knowns. The areas of individual knowledge, unknowledge, and knowns and unknowns are depicted in Fig. 2.1.

Yet man may still know that some future situations may, in principle, come into existence, e.g., the decline or renewal of an urban neighborhood. Other future situations, however, will be fundamentally different, compared to anything that existed before.

### Known Unknowns

Possible future situations include those that are mere reconfigurations of known situations, e.g., the renewal of an urban neighborhood in (almost) the same manner as had been observed somewhere else. Man knows that something like this may

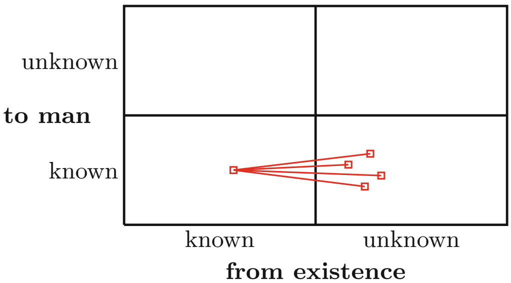


**Fig. 2.2** Models, forecasts, and scenarios are built on known unknowns, i.e., future situations that man can imagine (*red strokes*)

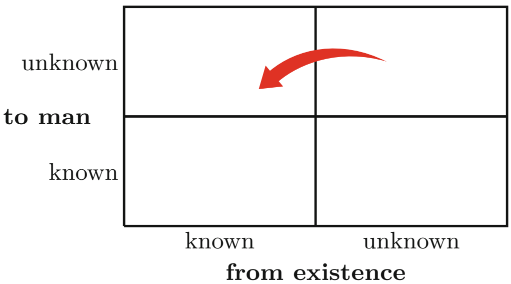


**Fig. 2.3** Whenever an unknown unknown comes into existence, it may or may not become known to man

(Footnote 2 continued)
He does not see the limitation in ontological novelty that is, in principle, unpredictable (an argument which is independent of human ignorance). Rather, he sees our capabilities as being too limited to disentangle the continuous succession of situations, and internal and environmental factors, that may lead to ever-new situations.

happen and may even try to influence the development (cf. Chap. 4). However, until it actually comes into existence, the particularities of the situation remain unknown.

The imagination or simulation of possible, future situations produces known unknowns (Fig. 2.2). Models are built, based on known knowns; by any means of imagination or simulation, situations that are not yet existent, i.e., unknown to the universe, are forecast. The known knowns in models include, e.g., a time series of past demographic developments, activities of real estate developers, or correlations among car traffic, citizens' healthiness, and economic productivity.

The consideration of known unknowns cannot afford the existence of novelty. Simulations or imaginations of future situations, based on known knowns and their variations, yield possible configurations of known situations—known unknowns. If there were something new, it could not be predicted, based on known situations.

**Unknown Unknowns**

No knowledge of novelty can be possessed by man, or by the universe, until it comes into existence somewhere first—whether it be by man's creative invention or not. Until it comes into existence, such novelty remains an unknown. Unknown unknowns cannot simply be imagined or simulated as configurations of known situations. As mentioned earlier, man could not have known what a city would be like before it first came into existence.

Yet novelty—the coming into existence of unknown unknowns (Fig. 2.3)—plays an eminent role in the course of events. And while it can only be in vain to seek to foresee when, and which, unknown unknowns could come into existence, it might be useful to understand *how* they come into existence. What—if anything—gives rise to unknown unknowns, to something new emerging out of existing situations?

The expectation is that through understanding more about unknown unknowns coming into existence, novelty can be identified, and the ground may be prepared on which (desired) novelty grows. In other words, what are the catalysts required for novelty to come into existence, and how can those catalysts be influenced?

A further conjecture is that there is a connection between the coming into existence of unknown unknowns and of nested systems. If, as hypothesized in Sect. 1.2, a better understanding of the forces underlying nested systems could make, e.g., urban development more effective, it is worth studying how novelty comes into existence.

## 2.2 The Emergence of New Qualities

From logical concepts, such as the one shown in Fig. 2.1 and described above, it can be expected that the future bears unknown unknowns that must involve novelty, i.e., something not yet existent that cannot be known by any means before it first comes into existence. Thus, situations out of which unknown unknowns, i.e., novelty, can come into existence, are required. Furthermore, such novelty must be more than a mere reconfiguration of existing parts.

**Propensities in Complex Systems**

The concept of propensities—possibilities of developments, i.e., dispositions inherent in each particular situation—offers an explanation for the manifold possibilities for unknown unknowns to come into existence in complex systems (Popper 1959, p. 34 and Ulanowicz 1996, p. 219). It allows man to understand that the continuous change of situations may generate propensities, out of which novelty may come into existence.

In complex systems, as defined in Sect. 1.1, every small change in a situation might lead to great overall changes. Out of the number of parts, and the diversity of their interrelations, there arises, at every point in time, a number of potential futures. These futures immediately change themselves upon the realization of any purposive decision, mutation, or 'natural' selection (cf. Sect. 1.3). In complex systems, individual choices might thus have a significant impact on the development of the complex system. This is what Christaller (1933, p. 113) pointed out regarding urban systems, as quoted at the beginning of Chap. 1.

Every situation comes with its own propensities, and choices are made instantaneously from within unique situations. Every single one of a succession of choices, or other changes in a complex system, generates *its own* set of propensities (Fig. 2.4), i.e., a new range of possible futures. The probability of a particular choice or change is then a disposition or property of the particular situation itself (Popper 1959, p. 34). Thus, in every situation, i.e., configuration of a complex system's parts and relations, lies "propensities, [which,] when realized, can change those situations so that new propensities appear, then new situations, and so on" (Simkin 1993, pp. 74–75).

This sequel of propensities—realized by choices of nature, i.e., without foresight, or of men, i.e., with purpose and foresight—opens the door to an ever-changing universe and, hence, to the possibility for novelty to come into existence. Although

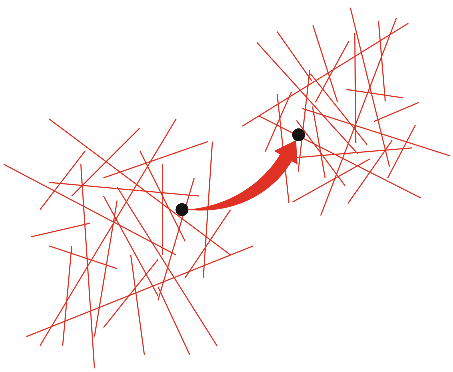

**Fig. 2.4** Every situation (indicated by *black dots*) comes with its own propensities—possibilities for future situations. The propensities are visualized as *red lines* in space, and a situation at a given time in a given place meets these lines of propensities. If a propensity is realized, the space of propensities is changed. Thus, in a sense, a first situation (*black dot on left*) *generates* the very next propensities (*red lines on right*)

not a necessity of the concept of propensities, novelty may come into existence out of changing situations and ever-new propensities.

### Emergent, Not Resultant

Complementary to such logical constructions as depicted in Fig. 2.1, there is evidence for novelty at several stages of the coming into existence of both natural and artificial systems (Fig. 2.5). This evidence ranges from the development of life out of inanimate matter to the development of consciousness in living beings and the coming into existence of economies or urban cultures. These, and many more novelties, are more than the sum of their (material) parts, i.e., more than what existed before they came into existence.

The coming into existence of an unknown unknown cannot be foreseen by what is known to man and/or the universe. Novelty is not explainable by reduction to its

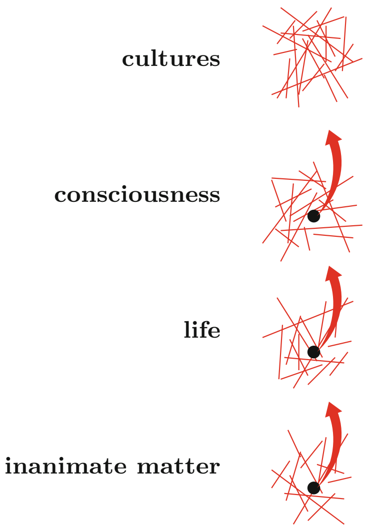


**Fig. 2.5** Some selected stages of the emergence (indicated by *red arrows*) of ever-new novelty since the beginning of the world

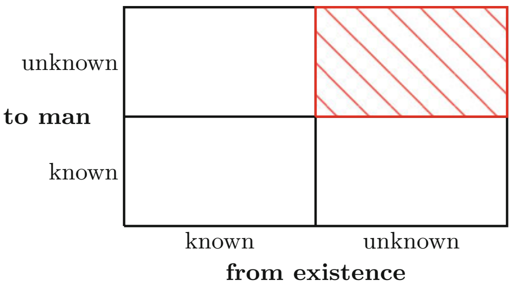


**Fig. 2.6** Real novelty cannot be reduced to previously existing qualities: Novelty comes into existence from the realm of unknown unknowns (indicated by *red hatched areas*)

parts, e.g., to atoms, molecules, or pre-urban cultures. Novelty cannot be *resultant*; it must be *emergent* (Hofkirchner 2011, p. 191).[3,4]

**More than the Sum of Its Parts**

Whatever kind of leap leads to something beginning so that more exists than it had prior to the moment that it began, i.e., more than could be chosen from knowns, it must involve the coming into existence of something emergent, not resultant. This concept of novelty requires the bold conjecture that *emergent qualities* cannot be reduced to previously existing qualities; otherwise, they could have been imagined as known unknowns. Likewise, they cannot be explained by cause-and-effect situations operating within these existing qualities.

> The meaning of the somewhat mystical expression, 'the whole is more than the sum of [its] parts' is simply that the constitutive characteristics are not explainable from the characteristics of isolated parts. The characteristics of the complex, therefore, compared to those of the elements, appear as 'new' or 'emergent.' (von Bertalanffy 1968/2006, p. 55)

Emergence requires new quality to come into existence (Fig. 2.6). The new quality, which is emergent, can be distinguished by its being more than the sum of its parts. The new quality cannot be explained by the qualities of its parts because there are no precursors of the emergent quality in its parts:

> Once there was no poetry in the universe; once there was no music. But then, later, it was there. Obviously, it would be no sort of explanation to attribute to atoms, or to molecules, or even to lower animals, the ability to create (or perhaps to pro-create) a forerunner of poetry, called proto-poetry. (Popper 1978, p. 352)

## 2.3 General Properties of Emergent Systems

Just postulating that emergent novelty cannot be explained by the parts alone—such as life or consciousness—explains, in fact, nothing. However, a further-developed theory of emergence, embedding the notion of emergence into a more comprehensive concept built around this notion, might add some explanatory value.

Subsequently, I will largely follow and extend the argument of Popper (1977), who conjectures that ever-new emergence leads to a *nested* arrangement of systems (Sect. 2.3.1), and that there is both *outward and inward influence* among the

[3] Hofkirchner refers to Blitz (1992).

[4] The genesis of this line of argument about emergence is generally attributed to J.S. Mill and G.H. Lewes. John Stuart Mill, in the sixth chapter (titled *On the Composition of Causes*) of the third volume of his 1843 *A System of Logic*, distinguishes 'mechanical' (homopathic) and 'chemical' (heteropathic) effects. For homopathic effects,"the composition of causes correspondent[s] to additive properties, while heteropathic laws give rise to constitutive properties" (excerpt from a lecture by Lloyd Morgan on *Scientific Thought*, 1912, quoted in Stephan 1999, pp. 75–76). The effects of heteropathic laws were termed 'emergent' in G.H. Lewes's 1875 *Problems of Life and Mind* (cf. Sawyer 2005, p. 32).

nested systems (Sects. 2.3.2 and 2.3.3).[5] On one hand, outward influence generates the propensities, out of which a new quality may emerge. On the other hand, rules of, and selection by, an emergent quality influences inward. I suggest that together, the enclosed and the enclosing systems in a nested arrangement form a *whole* (Sect. 2.3.4).

### *2.3.1 Nestedness*

With every emergent quality, new situations become possible. With every one of these new situations, further new propensities are generated, out of which even further novelty may come into existence. Hence, out of new, formerly impossible situations, it may become possible for new qualities to emerge.

What follows is a succession of *ever-new emergent qualities*, made possible by *ever-new propensities* (cf. Popper 1977, pp. 30–31). These nested systems exist without being designed as such by purposive human activities. And yet, nesting and nested systems potentially interfere with purposive human activities, e.g., in the field of urban planning. Urban systems are also nested, in that they are enclosed by other systems, e.g., regional systems, and in that they enclose other systems, e.g., urban districts.

Furthermore, the emergence of urbanity only becomes possible where a city exists already.[6] After the emergence of consciousness, cultural and social qualities emerged, among them economies and cultural codes, which, in turn and in combination with other qualities, made it possible for cities to generate further new propensities, out of which, e.g., urbanity could emerge.

In such a succession of emergent qualities, previously existing qualities become parts of newly emerged qualities; qualities become *enclosed* or “encapsulated” (Fuchs and Hofkirchner 2005, p. 29) by one another. This “leads…to a…theory of the universe, in which the world is composed of stacked layers of emergence” (Miller and Page 2007, p. 45).

From the succession of emergent qualities, one of the most universal features of natural and artificial systems follows: their arrangement into nested systems (e.g., von Bertalanffy 1968/2006, p. 27). Nested systems are like onions: one system inside another system, the outer system enclosing the inner one. For example, metropolitan

[5]Popper, as other authors, writes of upward and downward causation. I refrain from following this terminology for two reasons. First, given the potential of emergence of novelty, there may be no such thing as repeatable causation—but repeatability is key to the idea and usefulness of (rather mechanistic) cause and effect; I prefer to use ‘influence’ instead (which does not exclude causation). Second, upward and downward may imply a hierarchical relation, just as bottom-up and top-down do; I prefer to express the idea in line with the image of nested systems, where one system is nested *inside*, and not below, another.

[6]The material shape of a city is a result of the emerged qualities, e.g., in the form of immaterial ideas and (cultural) images that are guiding the activities of citizens in shaping the city. See also Footnote 7.

regions enclose cities and towns, which enclose districts, which enclose neighborhoods, which enclose micro-neighborhoods. The latter enclose even further systems, e.g., buildings in the physical realm and families in the social domain.

In his theory of central places, Christaller (1933, p. 26) explains spatially nested systems, in which a central place of relatively higher economic significance covers a region, which includes central (and remote) places of relatively lower economic significance (cf. Fig. 1.1a). With emergent quality being at the core of every system, it becomes plausible why an arrangement of nested systems (Fig. 2.7) is "fundamental in the general theory of systems…from elementary particles to…atoms, molecules,…cells…organisms and beyond to supra-individual organizations" (von Bertalanffy 1968/2006, p. 27).

### 2.3.2 Inward Influence

Every system in the arrangement of nested systems is defined by an emergent quality, reflected by rules that guide and select activities in the enclosed systems. E.g., after the emergence of a new quality such as urbanity—itself emerging out of situations in cultural and material systems—the (unwritten) rules of an urban place guide the activities of individuals in the city. In that way, the emergent system has inward influence (Fig. 2.8) on the (cultural and material) systems from which it emerged.[7]

New rules start to guide activities in enclosed systems, upon the emergence of a new enclosing system. An enclosing system's inward influence toward the enclosed

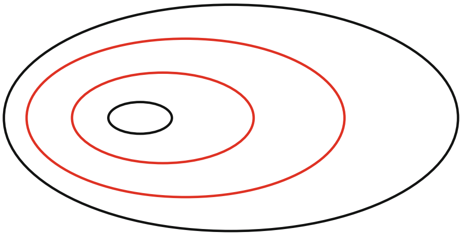

**Fig. 2.7** When through the emergence of a new quality the first system becomes enclosed by another system, a nested arrangement of systems comes into existence. Highlighted is a single nested relation, as it will be used in subsequent illustrations

[7] In the case of cities developing a (partly) fractal spatial shape, new rules guide the fractal development after the emergence of, e.g., cultural, esthetic, and social qualities. As a consequence, the fractal shape is not emergent, but the quality of the rules, which guide the fractal shape, is; the fractal shape itself is a resultant. As a further consequence, the concept of self-organization subsides. I.e., despite spontaneous activity—e.g., mutation or creative thought, both subject to selecting rules—which is not organized, there is no such thing as 'bottom-up' self-organization of parts. I hold that patterns that seem to be self-organized are, in fact, resultants guided by the rules of emerged, enclosing systems.

system is restrictive and prescriptive (cf. Fuchs and Hofkirchner 2005, pp. 29 and 31). It is restrictive in that situations that were possible before may not be possible any more, and prescriptive in that situations may become possible that were not possible without the emergent system. By virtue of its guiding rules, every emergent system may act back or even "exert a dominant influence" (Popper 1977, p. 35) upon the enclosed systems.

By restricting the enclosed systems, the enclosing system's inward influence is a selective one that includes choice-making. Whatever (purposive) activity is attempted in the enclosed systems, the enclosing system may or may not let it pass (Popper 1978, p. 348).[8] Either a purposive "choice process may be a selection process" (Ibid., p. 349), or the rules of the enclosing system's emerged quality may accept or reject the activity of the enclosed system. For example, a certain personal activity might not fit within the ethical or moral rules of the actual cultural system, and the activity subsequently might be suppressed.

New rules might as well guide and select such activities in the enclosed systems that support and maintain the emergent quality. The emergent qualities "prescribe the activities of the subsystems", i.e., of the enclosed systems (Haken 1981, p. 17). Thus, there is circular and continuous, autopoietic regeneration of a whole at work (cf., e.g., Maturana and Varela 1980, pp. 78–79 and Luhmann 2004, pp. 78, 108 ff.). For example, a central place system comes along with (unwritten) rules, through which the central place's relatively surplus importance and, hence, the central place quality, can be maintained. The roles of both the enclosed central and less central places are guided by the rules of the emergent system.

### *2.3.3 Outward Influence*

Besides inward influence, there is outward influence in complex systems (Popper 1977, p. 35). Outward influence (Fig. 2.9) is *generative*, in that it enables and maintains the emergent quality. However, outward influence may also lead to the breaking up of the emergent quality. Thus, on one hand, emergent systems may only come into existence if changing situations in existing systems generate ever-new propensities,

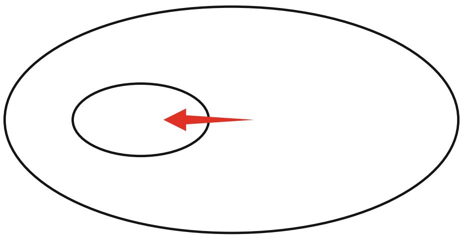

**Fig. 2.8** There is inward influence via guiding and selecting rules from the enclosing system

[8]The cited author refers to Cambell (1974), Sperry (1969), and Sperry (1973).

out of which emergence may occur. On the other hand, the continued existence of the emergent system is based on the continued existence of the enclosed systems (Fuchs and Hofkirchner 2005, p. 30).

Activities of outward influence can be either purposive, i.e., with foresight, or untargeted; they can either fit, or be rejected by, the enclosing system's rules of inward influence. The activities of the enclosed systems can also generate propensities, out of which the emerging quality changes. This can be exemplified in social systems where emergent cultural and political systems continuously change. In the most extreme cases, such as a revolution, citizens may break up the political system that encloses them. Similarly, decay of enclosed systems could destroy the enclosing system, i.e., the emergent quality and its rules.

Out of ever-changing propensities in existing systems, eventually an enclosing system will emerge. This could explain why cultural, economic, political, and other systems eventually emerge from the activities of man. Similarly, in natural systems, free elementary particles may form and then get enclosed in atoms; these particles form and get enclosed again, and so on. This leads to an endless realization of ever-new *Emergent Nested Systems.*

### 2.3.4 Wholes

Together, the enclosing and enclosed systems form a whole. The whole is discernible by the quality of the enclosing system and by its rules that apply to the enclosed system. The enclosed system becomes "sublated" into the whole (cf. Fuchs and

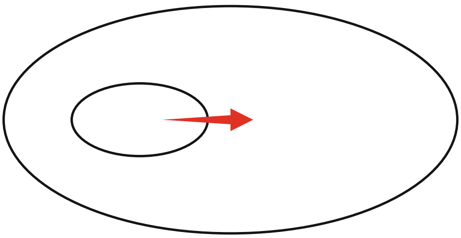

**Fig. 2.9** There is outward influence through activities in enclosed systems that generate propensities, out of which the enclosing quality might be changed, or new enclosing quality might emerge

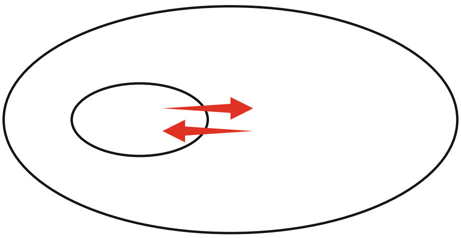

**Fig. 2.10** Together, the emerged enclosing system and the generative enclosed system form a whole

Hofkirchner 2005, p. 29). Without an emergent quality, there will be no whole, but only an assembly of parts.

Generative outward influence, and guiding and selecting inward influence, makes the enclosed and enclosing systems an interdependent whole (Fig. 2.10). On one hand, the emergent quality and the enclosed systems are linked by inward influence. On the other hand, the new quality could not even arise without outward influence.

In a whole, neither the enclosed systems nor the enclosing system stand alone. For example, in a system of central places, the whole, i.e., the central place system, and its parts, i.e., the region and the central places, cannot exist independently. There is mutual influence between the enclosing system and the enclosed ones, i.e., between the whole and its parts.

## 2.4 Fast and Slow Systems

I suggest, building on arguments brought forward by, e.g., Simon (1962), that a further property of ENS is the relatively slower speed of the enclosing systems, as compared to the enclosed ones. Relatively fast outward influence of enclosed systems may generate, change, or even break up the enclosing system. Thus, the enclosing system may be destroyed if it cannot adopt the changes of the enclosed systems.

If this hypothesis holds true, (the relation between) enclosing and enclosed systems could be discerned by measuring the speed of their internal activities, e.g., of their turnover and exchange rates, and/or their rate of change. Also, the slow/fast relation holds explanatory power for outward and inward influence in emergent systems. Generative activities must be able to adapt quickly to changes of rules, just as rules would not be effective if what they governed could not keep up with the changes. In the same way, revolutions breaking up enclosing systems can only work because the enclosing systems cannot adapt quickly enough to the activities of the revolutionists.

The understanding of fast and slow systems provides a means to understand complex systems beyond the hardly useful ‘everything is connected with everything else’ paradigm. In particular, tools and methods developed to effectively influence emergent and nested, i.e., complex, systems, might aim at influencing the relations between relatively faster and slower systems.

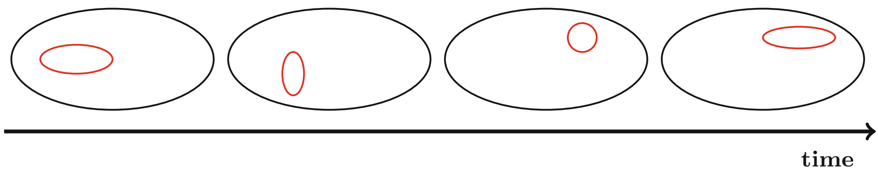


**Fig. 2.11** The enclosing system changes slower than the enclosed one

**Systems Change Over Time**

There is evidence for a link between a system's speed of operation and its position in the arrangement of nested systems. For example, while the individual's habits change relatively fast—every couple of years—the cultural system of a society that guides the individual's habits changes much slower—every couple of decades (cf. Fig. 2.11). Man gives rise to social systems, e.g., political, cultural, or economic systems that constrain a group or society; the social systems have a slower pace of change than the individuals within them. This supports the conjecture that a relatively slower system is enclosing a relatively faster one.

This observation for social systems is in perfect analogy with von Bertalanffy's description of biological systems:

> The living organism is a hierarchical order of open systems. What imposes as an enduring structure at a certain level, in fact, is maintained by continuous exchange of components of the next lower level .... As a general rule, turnover rates are the faster the smaller the components envisaged. (Ibid. 1968/2006, p. 160)

Simon (1962) introduces the concept of "nearly decomposable" systems, i.e., of systems, in which faster subsystems are encapsulated by slower ones[9]:

> It is well known that high-energy, high-frequency vibrations are associated with the smaller physical subsystems and low-frequency vibrations with the larger systems into which the subsystems are assembled. (pp. 475–476)

Similarly, Haken (1977, pp. 191 ff.) and Weidlich (1999, p. 139) observe faster dynamics in subsystems than in the "global conditions" of the environment. In settlement systems, e.g., "fast processes take place on the *local microlevel*" (buildings, traffic infrastructure, etc.), but "slow processes take place on the *regional macrolevel*" (whole settlements) (Ibid., p. 138).

**Enclosing Systems Are Slower**

The examples above further support the conjecture that enclosing systems are characterized by a slower speed of change than the systems they enclose. E.g., slowly changing social systems guide the relatively fast activity of man, whose overall, relatively slow body guides the relatively fast, biological activities of its organism.

Such relations between slow, enclosing and fast, enclosed systems appear throughout the animate and inanimate world. These relations apply to natural and man-made systems alike, and they interrelate all types of systems through guiding and selecting rules, as well as through generative activities. Simon (1962) notes that:

> "[i]t is probably true that in social and in physical systems, the higher frequency dynamics are associated with the subsystems, the lower frequency dynamics with the larger system. It is generally believed, for example, that the relevant planning horizon of executives is longer the higher their location in the organizational hierarchy" (Ibid., p. 477).

[9] The term "nearly decomposable" refers to Simon's claim that, when analyzing complex systems, the relatively faster activities within systems may be neglected, and only the slower activities of the enclosing system have to be analyzed together with the few relevant interactions between the faster and the slower systems. Hence, according to Simon, systems can nearly be decomposed—nearly only—because some of these activities in between systems are relevant (see also Sect. 3.3.1).

From the existence of enclosing systems, Simon, like Haken and Weidlich, derives the ability to understand nested systems from the enclosing conditions of the relatively slower system alone (cf. Sect. 3.3.2). Such a conclusion, however, neglects the impact which (individual) activities in the faster system may exert on the slower one.

**Enclosed Systems Are Faster**

Finally, the relation between slow, enclosing and fast, enclosed systems can explain the important properties of outward influence. It is not only that the slower system emerges from the faster ones, but also that the faster, more dynamic system has the power to change or even break up the slower, enclosing system.

For example, Holling (2001a), following up on Simon (1973)s work, ascribes the role of "triggering a crises," starting a "revolt," and invigorating faster systems. To slower systems, he ascribes the role of "constraining, " setting "the conditions," guiding, and protecting (Holling 2001a, pp. 397 ff.).[10]

For a "revolt" of a faster system, he provides the example of "local activists succeed[ing] in their efforts to transform regional organizations and institutions, because the latter have become broadly vulnerable" (Ibid., p. 398). If not through revolution, then in a more subtle way,"ideas (generated in the faster system) can become incorporated into slower parts of the panarchy, such as cultural myths, legal constitutions, and laws" (Ibid., p. 401).[11]

Another example of interrelations between fast and slow systems is the interplay between lifeforms and the atmosphere. While the atmosphere has set the conditions under which life can develop, lifeforms themselves have had great impact on the atmosphere, eventually changing it into the oxygen-rich one we know today. However, now it is feared that man may have a similarly tremendous impact on the atmosphere, if released greenhouse gases and other pollutants are able to change the enclosing system.

[10]Holling (2001a) and coworkers (e.g., in Holling 2001b) in particular develop a model for adaptive (eco-)systems that go through cycles of resilience and vulnerability. They claim that layers of such adaptive systems stack up from spatially small to large and from fast to slow.

[11]By the term 'panarchy,' the original authors mean a guiding system which encompasses all other adaptive systems in a nested, but not top-down, manner—"a nested set of adaptive cycles" (Holling 2001a, p. 396).

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