Universiteit Utrecht

Bachelor Thesis

Scientific Modelling and Emergence

Fleur Petit (f.m.petit@students.uu.nl)
Student Number: 5583837
Faculty: Humanities
Department: Philosophy and Religious Sciences

Supervisors:
Dr. Jesse Mulder
Dr. Annemarie Kalis

August 24, 2017

Contents

Abstract

If different models of the same process represent alternate groupings of the same fundamental components, why wouldn't one model featuring those components suffice? Can a macro-scale model tell us something more about how a process evolves? Even if the relations and interactions between the different groups of components are in fact a combination of all the relations between individual components? In this thesis I argue for a representational pluralist position, i.e. I argue that different models of the same process can be complementary. To establish this idea, I first illustrate how a scientific model of an information processing system can be formed, using an example from the Cognitive Sciences; a model of working memory[1]. Consequently, different rationales are explored that could support the idea that different models of the same process can be complementary. The theoretical framework provided by Gillett will be employed to clarify the different viable views.[2] To illustrate the two main views, scientific reductionism and scientific emergentism, an example of a cellular automaton will be employed. The first position, scientific reductionism, states that all the relations and interactions between the different groups of components are, in fact, relations between individual components. The main challenge of the scientific reductionist is to somehow combine this idea with the idea that macro-scale models can be complementary in some cases. The second position, scientific emergentism, states that there might be cases in which relations between groups are not a set of relations between individuals, but rather only exist between groups. With as a result that not all behaviour of the individual components is accounted for by local interactions and relations. The main challenge of the emergentist is to explain how individual components can be influenced by relations that hold on a macro-scale, between groups. The example of the cellular automaton helps to see what the differences between both positions are, but does not yet show how the second position is actually thought to work. In the last section I will attempt to further elaborate on this, but the challenge will stay far from resolved.

[1] Alan Baddeley, "The episodic buffer: a new component of working memory?" *Trends in Cognitive Science* 4 (2000): 417-423.

[2] Carl Gillett, *Reduction and Emergence in Science and Philosophy* (Cambridge: Cambridge University Press, 2016).

Scientific Modelling and Emergence

Fleur Petit (f.m.petit@students.uu.nl)
studentnummer: 5583837

August 24, 2017

Introduction

Topic and Relevance

Different sciences seem to make different contributions to our means to predict and manipulate our environment. Sometimes the same process or system can be characterised by different scientific models. Depending on the scale of the relevant observations, and the purpose of the research of the system or process, the components might be grouped differently in the subsequent model. This results in models of the same process that involve different groups of the same set of components and different interactions between these groups. It is important to learn more about this, because it helps us to determine if one fundamental science would suffice to analyse every process and if it could provide us with answers to all the questions we can ask about this process.

Research Question

From the idea that a process can be represented differently depending on what we want to find out about this process, it does not follow that there are different correct answers to the same questions about the process. It is only stated that different questions might require a different approach. With this different approach, it might be possible to measure different values of different groupings of components, resulting in a different model. However, if the different groupings result in different relations between the groups and can explain different aspects of the same process, could it be that one model can explain why certain values and relations hold in another model, while this other model cannot explain the complete process it represents? Does that mean that the set of interactions characterised in this other model is not the complete set of interactions that are relevant to the values that we find? How can we best understand the relation between different representations of the same process or model? Do the different aspects of the process that they represent somehow influence each other? If we want to adhere to the idea that different models of the same process can be complementary, then what views, on how interactions between components of a system work, are we left with?

Argumentation Structure

I will start by sketching an understanding of scientific modelling. I argue that, in order to model the world, processes or entities need to be separated. To illustrate this understanding of scientific modelling, a model of working memory is employed. We will see that, the way we individuate different entities or processes and the relations between them, might differ depending on what we want to find out, at what level we observe and how we manipulate what we observe. I argue for a position that accepts that many different representational schemes, in the predicates of many sciences, are needed to express all truths about nature. Consequently, we will ask ourselves whether emergence is needed for this position to be true.

To answer this question, we need an understanding of what emergence is. For a clear definition of the concept, I employ a theoretical framework provided by Carl Gillett.[1] I clarify his theory by means of an example of a cellular automaton. Two viable views are introduced: Mutualism (scientific emergence) and Fundamentalism (scientific reductionism). Both views come with their own opportunities and challenges. I will argue that, although the previously introduced position on scientific models can be true in scientific reductionism, scientific emergence is not yet excluded.

In the last chapter, I focus upon the challenges of Mutualism. We will first establish a more thorough understanding of the concepts involved and then assess what implications this understanding has for some of the established counterarguments. It appears that there still is a lot of research to be done, before we are able to conclude that either Mutualism or Fundamentalism is correct.

[1] Carl Gillett, *Reduction and Emergence in Science and Philosophy* (Cambridge: Cambridge University Press, 2016).

1 scientific modelling

1.1 Introduction

In the below I assume that the primary goal of scientific modelling is representing how the world works. What causes things to happen as they happen? It is an attempt to approximate the structure and workings of reality - whatever this is taken to be. It is, however, very important to retain a distinction between model and reality. Reality has many facets, and I would like to argue that it is simply not possible to capture all of these in one single model on one scale, because different kinds of questions require different kinds of scales and methods of observation. Moreover, if all we have is a model representing all proceedings on the most fundamental scale, this does not mean that we also know how to derive models that represent what can be observed on a macro-scale from our fundamental model.

1.2 Different Scales and Different Types of Questions

What do I mean by scientific modelling? Let's say that the world is constantly changing. I assume that if there is a change, there is a difference between the state the world is in before that change and after it. A scientist, pursuing his goal as I formulated it, would like to know what constituted this change. In order to characterize the change and to make a model of all the elements involved, one first has to be able to identify *different* elements in our observation of the change. But, how do I "cut out" those elements from my picture of the world? How can I identify separate parts?

One method would be to assume there to be a certain structure of elements and interactions between them, that would result in the change observed. This assumption can be tested. For example by manipulating the values of the different elements in this structure and checking if the results of this manipulation are as predicted on basis of this structure. When this is not the case, it might be uncertain if the model or the method of manipulation was wrong and new tests can be designed to research either stance and again these results might be just as uncertain. Yet, we can still point out which model is more likely to be true, given our assumptions in combination with our test results. Conclusions about which model is more likely to be true might have to be reviewed when new results counter our previous assumptions and conclusions, but I don't see that as a problem to the scientific practice. I think it is not so outrageous to assume that fallibilism is widely accepted in the sciences. How this can be the case is a very interesting question, but not so relevant for the purpose of this thesis.

The point is, that depending on the scale on which I observe a natural process,[2] I might "cut out" different entities or relations. If I would want to make a simple flow diagram of a part of the world during a certain time, then I need to decide what goes into the black boxes and what the relations between those boxes stand for. What I put in one box on one level, I might not like to group together on a smaller scale. Simply, because I have different cues on smaller scales to inform my boxing decisions than I have in observations on a larger scale. Moreover, how I box my observation data is also influenced by the kind of question I am asking.

1.2.1 Marr's Different levels

Marr separates three levels on which questions in Cognitive Science can operate: the algorithmic level, the computational level and the implementation level.[3] Those levels are not separate layers in the world, rather they reflect different ways to approach and investigate phenomena in Cognitive Science. Each approach helps us to find answers to different kinds of research questions. On the computational level, questions are answered about what causes the system to act as it does. On the algorithmic level, issues concerning which steps are involved in the behaviour are analysed, and on the physical level, the physical realizers of the analysed issue are relevant. The way a theory or model of a system is consequently designed depends, in the end, both on the observation of properties in the world and on the type of question asked. Due to the latter dependence, a model of the same process might not be reducible to another type of model of this process, because it would fail to answer the initial question. A theory about what caused something to act in a certain way, might be different from a theory about which steps are involved.

1.2.2 Time-space continuum Newell

Similarly, I would argue that different types of questions might require observations on different scales. Because some processes might arise on an interpersonal level, where questions of responsibility or intention make sense,

[2] A natural process is, in my understanding, a sequence of changes in the world with some boundary conditions. A change is a situation in which the total state of the world is slightly different than before. I will use the words process and system interchangeably.

[3] David Marr, "The Philosophy and the Approach," in *Vision: A Computational Investigation into the Human Representation and Processing of Visual Information* (San Francisco: W.H. Freeman and Company, 1982).

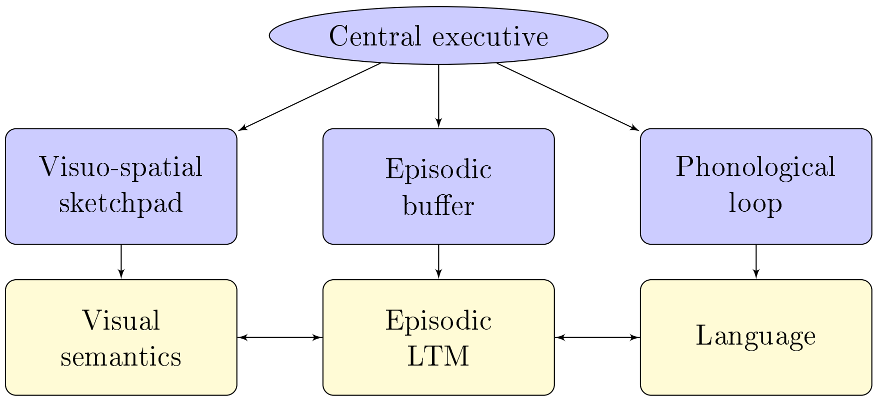


Figure 1: Baddeley (2000) version of a multicomponent working memory model. The arrows express dependency relations between the different components.

while other questions, about how these things are implemented, are best answered by physical models expressing what is relevant to the process on a neural scale. Cognitive scientists adopted from Allen Newell the method of clearly defining on what scale in time and space the process under consideration can be observed.[4] If I have a model about working memory (WM) for example, it makes no sense to take into account single neurons only and not the properties of their patterns as a whole. Memory is something that is important to explain our further actions and involves, among other things, concepts that relate to the behaviour of *a person*. The interaction between parts of his brain is less relevant, if I just want to know what a whole *person* does when doing a working memory task, during the time-span of the task. Taking a smaller time-scale would leave me with a model that contains many irrelevant details and that subsequently might miss the point. Let's take the Baddeley (2000) version of a multicomponent working memory model as an example (Figure 1).[5]

1.2.3 Example: Models of Working Memory

At this point I am mainly interested in how the multicomponent model of working memory (Figure 1) was formed. In 1964 Conrad and Hull came up

[4] Allen Newell, *Unified Theories of Cognition* (Massachusetts: Harvard University Press, 1990).

[5] Alan Baddeley, "The episodic buffer: a new component of working memory?", *Trends in Cognitive Science* 4 (2000): 417-423.

with a very influential model of short-term memory.[6] During their research on short-term memory, they found that lists of similar sounding elements, are more difficult to remember than lists of words that sound differently. Independently of whether the list was presented auditorially or visually. They modelled short-term memory storage, consequently, as a unitary system that relies on an acoustic code. In a reflection on this earlier model Baddeley writes:

> By the late 1960s, the evidence seemed to be swinging firmly in the direction of abandoning the attempt to explain STM [*short term memory*] in terms of a unitary system, in favor of an explanation involving a number of interacting systems, one of which was closely identified with the extensive evidence accumulated from verbal STM.[7]

Here, we have a situation in which, apparently, evidence leads to a preference of a division of a system into several separate systems, instead of representing it as a unitary system. What kind of evidence can inspire such a division? First of all, based on similar evidence as Conrad's, Baddeley's model of short-term memory introduces a phonological loop. List elements are rehearsed subvocally in order to remember them. This process can be suppressed by repeatedly saying "the" while being presented with list-items. Interestingly, while the phonological loop is suppressed, one can still remember lists of up to five visually presented digits. This implies that the phonological loop is not the only system involved in short-term memory. If inhibiting visual memory, which is involved in remembering the digit span, does not affect the performance on a task involving subvocal rehearsal, it is concluded that visual memory and the subvocal rehearsal rely on independent systems. This is how the visuo-spatial sketchpad is separated as an independent system from the phonological loop. In a similar way, the episodic buffer is separated. In the episodic buffer, it is thought that different information from different systems comes together to form meaningful chunks that can be saved in long-term memory. It is separated by showing that it is possible to bind information even when you cannot remember words or remember and manipulate elements visuo-spatially. The other way around, when the episodic buffer is suppressed, words can still be remembered and visuo-spatial manipulation still works, but it becomes harder to

[6]Richard Conrad, Hull, A.J., "Information, acoustic confusion and memory span," *British Journal of Psychology* 55 (1964).

[7]Alan Baddeley, Michael W. Eysenck and Michael C. Anderson, *Memory* (New York: Psychology Press, 2015), 43-44.

make meaningful chunks of the information that is processed. This method of separating different systems by looking at the effects of suppressing one on the other and the effects of suppressing the other on the first one is called *double dissociation*. It is used very regularly in Cognitive Sciences.

We have seen now that there are three systems in Figure 1, individuated using this method. But, what about the other elements? The yellow blocks are not a part of working memory but are thought to be part of a system that depends on it: the long-term memory (LTM). It is separate from working memory. There are cases of patients who can still remember sequences of words for a short time and use visuo-spatial manipulation to do calculations, while they cannot make meaningful chunks of new experiences and store those in their long term memory.[8] The long term memory components are added to the model so that one can get a gist of how working memory influences long term memory. The details of the interactions in the LTM itself are omitted for the goal of this particular model. The bottom six blocks (I will come back to the central executive later, since it requires some extra attention) would form an explanation on the algorithmic level of Marr. It explains something about the different systems involved in working memory, yet it explains very little about how this is physically implemented or why it works this way.

1.2.4 Replacing the working memory model

So far, I used the example of the WM-model to illustrate how different systems are individuated. Now, another interesting question would be: "Could I replace this model of the systems involved in working memory by a model of their physical implementation?" I argue this is not possible in this case.

One of the reasons is, that we have to have an idea about what we think working memory to be, before we design tasks that will show what systems are involved. If we did not think about it involving a system like the phonological loop in the first place, we might never have separated the visuo-spatial sketchpad. Of course, the idea of the phonological loop is based on the fact that lists of similar sounding elements are more difficult to remember than the ones that sound different. There are however different models that can explain this effect just as well and maybe other aspects better.[9]

Baddeley comments that "It [*a multicomponent account of WM*] has proved durable and widely applicable, but should be seen as complementary

[8] Clive Wearing is a common example of a case study.

[9] For example: Klaus Oberauer and Laura Hein, "Attention to information in working memory," *Current Directions in Psychological Science* 21 (2012): 164-169.

to a range of other approaches, rather than *the* theory of working memory."[10] For a fuller grasp of what working memory is, different approaches prove to be illuminative. Just as when I would look at a city and can see all the different buildings from afar by looking at the skyline. I would be able to tell you about all the buildings that make up the city, yet I would learn more about it when I look at the buildings from up close and from the other side. My talk of bricks and mortar would make little sense to you if the instruments you use to observe the city make it impossible for you to see anything but the skyline and the dark building-contours. Yet, you will learn some more about it by hearing about the buildings actually being made up out of bricks. Likewise, I might not understand your talk about contours, if I never stepped back far enough te see what the skyline looks like. Both approaches give me a more elaborate understanding of what the city is, and because they describe different aspects of it, one cannot be put in terms of the other, without describing different observations.

Yet, observations on one scale, from one approach, can inform how observations on another scale have to be interpreted. When I conclude from certain task-performance results that the phonological loop and the visuo-spatial sketchpad are different systems, but see that, when I put my subject into an fMRI scan and let him do the same task, the active brain areas overlap, I might have to reconsider my model. I might want to look for an adaptation of the model that ensures that my new observation makes more sense?

Another reason why different approaches might be illuminative is that sometimes it can be difficult to formulate general rules to reason from one scale to another. On a macro-scale, divisions of separate systems are based on the blocking of certain processes observed on that scale. In this way I find answers to questions posed on an algorithmic level. If I want to know something about the physical implementation, I might look at the different parts of brain tissue, which I individuate, not only by suppressing one area and looking if it effects on others, but also simply by looking at its differences in shape and density of cells. Brodmann divided different brain areas by looking at the differences in cellular structure.[11] There is no direct reason to expect this division to nicely fit with the distinctions on a macro-scale, since they are informed by totally different observations of how these areas work together to form certain cognitive abilities. It is not always possible to

[10] Alan Baddeley, Eysenck and Anderson, *Memory*, 42.

[11] Korbinian Brodmann, *Brodmann's Localisation in the Cerebral Cortex based on Cytoarchitectures. The Priniples of Comparative Localisation in the Cerebral Cortex based on Cytoarchitectonics*, trans. ed. Laurence J. Garey (New York: Springer:2006).

tell from looking at a micro model what macro interactions are realised by the components that are represented in this micro model. The same macro model can have different micro models that realise it and the same micro process can have a part in different macro models of different aspects of the same process. In the latter case these different macro models represent alternate groupings of the same tokens, using different grouping criteria and therefore highlighting other parts of the process.

1.2.5 The Central Executive

A very important part of Baddeley's model has been lacking a proper introduction so far: the central executive. A major function of the central executive is attentional focus, the ability to direct attention to the task at hand.[12] Patients with frontal lobe damage often fail at cognitive tasks that involve attentional focus. It is hard to say, however, if it also works the other way around: if there are people with a working central executive that don't have a fully operative visuo-spatial sketch-pad, episodic buffer and phonological loop, since attentional focus is a very basic need to allow any of them to work correctly. It is also very difficult to test attentional focus by a separate task that does not involve any other system, that is needed to perform the task. The central executive is best understood, not as a system on the same level as the visuo-spatial sketch-pad, episodic buffer and phonological loop, but as a system that is involved in all three. The idea that switching attention might always be the function of one single attentional system might be an oversimplification. Some aspects of switching happen automatically, while others are more attention demanding. Attention of what? How does that work? In order to answer this question we could follow Dennett's idea of the general method of an AI-researcher:

> The AI researcher starts with an intentionally characterized problem (e.g., how can I get a computer to understand questions of English?), breaks it down into sub-problems that are also intentionally characterized (e.g., how do I get the computer to recognize questions, distinguish subjects from predicates, ignore irrelevant parsings?) and then breaks these problems down still further until finally he reaches problem or task descriptions that are obviously mechanistic.[13]

[12] Baddeley, Eysenck and Anderson, *Memory*, 79.

[13] Daniel C. Dennett, "Why the Law of Effect Will Not Go Away," *Journal of the Theory of Social Behavior* (1975): 80.

The breaking up of a more intentional explanation of a system into mechanically explained parts, without denying the first explanation its representative status is specified in Marvin Minsky's *Society of Mind*[14]. He approaches the mind as a collective of "agents" that form a close parallel with the sort of systems we have been discussing so far. He explains how the breaking up of cognitive abilities into simpler systems, until we have very basic almost mechanistic principles, contributes to our insight of how these cognitive abilities work. He emphasizes however, that this does not mean that these mechanistic principles are capturing all there is to say about the mind. He has a nice example of a mouse being contained by a box:

> What is Life? One dissects a body but finds no life inside. What is Mind? One dissects a brain but finds no mind therein. Are life and mind so much more than the "sum of their parts" that it is useless to search for them? To answer that, consider this parody of a conversation between a Holist and an ordinary Citizen:
>
> **Holist:** "*I'll prove no box can hold a mouse. A box is made by nailing six boards together. But, it's obvious that no box can hold a mouse, unless it has some 'mousetightness or 'containment. Now, no single board contains any containment, since the mouse can just walk away from it. And if there is no containment in one board, there can't be any in six boards. So the box can have no mousetightness at all. Theoretically, then, the mouse can escape!*"
>
> **Citizen:** "*Amazing. Then what* **does** *keep a mouse in a box?*"
>
> **Holist:** "*Oh, simple. Even though it has no real mousetightness, a good box can 'simulate' it so well that the mouse is fooled and can't figure out how to escape.*"
>
> [...] The secret of a box is simply in how the boards are arranged to prevent motion in all directions! That's what *containing* means. So it is silly to expect any separate board by itself to contain any *containment*, even though each contributes to the containing.[15]

Crucial in this passage is that the containment of the mouse is not only the result of the properties of the boards themselves, but also involves their *arrangement*. *Containing* is property of the whole composition that is not

[14] Marvin Minsky, *Society of Mind*, (London: Pan Books Ltd, 1988).
[15] Minsky, *Society of Mind*, 28.

found in the properties of the boards taken separately. Moreover, Minsky recognises that the properties involved in models on de smallest levels can be very different from the ones (perhaps less mechanistically characterised) involved in models on a macro-scale and that there is no direct reason to assume that micro-scale models are semantically omnipotent.

> The smaller two languages are, the harder it will be to translate between them. This is not because there are too many meanings, but because there are too few. The fewer things an agent does, the less likely that what another agent does will correspond to any of those things. And if two agents have nothing in common, no translation is conceivable.[16]

The idea here is that, what a collective of components in a complex system does on a higher level, might be so different from the simple rules followed by the lower level components, that what one is doing cannot be expressed in terms of the other's proceedings. Minsky recognises some kind of semantic anti-reductionism.

Kitcher also has a insightful passage explaining that, even if in the end all models are deduced from simple rules on the most fundamental level, still, what is relevant for the purposes of giving one explanation, may be quite different from what is relevant for the purposes of explaining a model used in giving that original explanation.[17] He states that sciences operating on different levels have different *patterns of reasoning*.[18] This idea has some parallels with the idea of the different levels of Marr and different questions being relevant for research on each level. A pattern of reasoning is seen as a sequence of schematic sentences, which are instantiated in answering some of the accepted questions of a science at a time. "Schematic sentences" are sentences in which certain items of nonlogical vocabulary have been replaced by dummy letters, together with a set of *filling instructions*, which specify how substitutions are to be made in the schemata to produce reasoning. Depending on the accepted questions in a science at a time, the accepted phenomena, the common language used to talk about these phenomena, the sets of experimental procedures and methodological rules, the pattern of reasoning might differ.[19] Each science that operates at a different level can be thought of as

[16]Minsky, *Society of Mind*, 67.

[17]Philip Kitcher, "1953 and all That. A Tale of Two Sciences," *The Philosophical Review* 93 (1984): 348.

[18]Kitcher, "1953 and all That. A Tale of Two Sciences," 370.

[19]Kitcher, "1953 and all That. A Tale of Two Sciences," 352-353.

using a certain language to formulate the questions it deems important and as supplying patterns of reasoning for resolving these questions.[20] Because of these differences in patterns of reasoning, methodological rules, language to talk about phenomena and sets of experimental procedures, distinctions that are made on one level, like the distinction between long term memory and short term memory, might be completely meaningless at a level where there is nothing to relate to like memory, because all that is relevant there are the mechanistic relations between components.

1.3 Conclusion

The idea that I have been trying to sketch so far is the following: in order to model the world, processes or entities need to be separated so we can specify the relations between them and see how they influence each other. How we individuate different entities or processes and the relations between them might differ, depending on what we want to find out, at what level we observe and how we manipulate what we observe. The method of double dissociation, blocking one processes to find out how this influences another, and then blocking the other to find out how it influences this process, is an example of a method that could be used. It gives insight in how things hang together.

Moreover, observing at different scales, using different methods might help us learn more about different aspects of the same process. It teaches us what influence it has in the answers on different kinds of questions. Both the top-down approach where we begin at the macro-observations and break them down into different parts, to look how these parts realize the macro-processes, and the bottom-up approach where grouped sets of micro-observations based on their individual properties are connected to see in what kind of behaviour it will result, are employed in the sciences. Because both approaches might use different methods to group components of a process, these two approaches might not fit one-to-one. Moreover, they might be employed to answer different kinds of questions and in that way neither of them is superfluous, even if they are describing the same process, because they explain different aspects of it.

My conclusion is that, given all this, in some cases a model of a process on one scale cannot be expressed by a model capturing the same process on a smaller scale. Thus, I adopt a representational *pluralist* position[21], which accepts that many different representational schemes, in the predicates of

[20] Kitcher, "1953 and all That. A Tale of Two Sciences," 370.

[21] Carl Gillett, *Reduction and Emergence in Science and Philosophy*, 149.

many sciences, are needed to express all truths about nature. Now my question is, for this to be true, do we need emergence? Does there need to exist something extra on top of the components for a representational scheme talking about the collective to have explanatory relevance?

2 A Theoretical Framework

2.1 Introduction

Gillett has formulated a framework to characterise the ontological commitments of scientific models. This will help us to see why something like scientific emergence would be introduced and what the related notion of machretic determination means.

2.2 Compositional Explanations

Gillett explains that the kind of explanation, that is often used in the sciences and that we have roughly characterised in the above, is a compositional explanation. A compositional explanation in the sciences is a clarification of a natural phenomenon observed on one scale, by dividing it into different components observed at a smaller scale, and explicating how the component interactions relate to the macro-scale observation. Just the existence of compositional relations on themselves does not necessarily imply reductionism. In the next section this will be further explained.

Components can be individuated by analysing their influence on changes in behaviour of other components, that together lead the total system to work as it does. Much of the complex behaviour of collectives seems to emerge from components that follow simple rules. One of the merits of studying what components compose this complex behaviour, is that these simple rules can be modelled mathematically. This opens the possibility for a very exact analysis of how much a model agrees with the empirical observations. An example is a model of the flocking of birds by Reynolds,[22] in which the behaviour of the whole swarm can be explained and predicted by modelling simple boids that each follow their own rules. These rules only involve their direct neighbours, yet together they compose a large structure that shows complex behaviour. The same approach is used in many different sciences.

[22] Craig Reynolds, "Flocks, Herds, and Schools: A distributed behavioural model," *Computer Graphics* 21 (1887): 25-34.

A compositional relation is non-productive because it does not involve two relata that are wholly separate. The composition is not something that is produced by the components, because it is not separate, nor do the components cause the composition in a sense where the cause exists separate from its effect. The term "upward causation" (and "downward causation" for that matter) is a rather unfortunate choice, because it makes one susceptible to confusion about the temporal priority of the relata. Stating that components $X_1 - X_n$ cause Y, might lead to confusion about the temporal extension of the relation; it seems as if the components come first and are followed by their effect, Y. But, Y is not the effect of $X_1 - X_n$, Y is in some sense $X_1 - X_n$. This means not that everything we say or know about $X_1 - X_n$ individually, exhausts everything there is to be said or to be known of Y, the collective $X_1 - X_n$ might very well exhibit real novel, collective propensities at a different scale. An example supporting this claim that we saw earlier, is the example of the box containing a mouse. None of the individual boards has any "containment", this is a novel property of the box as a whole.

2.3 Determination and Aggregation

Both scientific reductionism and scientific emergentism employ compositional explanations. So what is the difference?

To clarify the relative position of the scientific reductionist and the scientific emergentist, we now turn to look at their stance in questions about aggregation and determination. This will help us to more clearly separate three distinct positions in the debate.

The scientific reductionist that holds the simple view of aggregation to be true is termed the Simple Fundamentalist. According to this position the dispositions of components in simple collectives in isolation can be added up to result in the behaviour of components in complex collectives. The dispositions of components in complex collectives simply result from the same dispositions as they have in simpler collectives, but then aggregated.

The scientific reductionist that holds the conditioned view of aggregation to be true, does contend that components have new, different dispositions in complex collectives than in simple collectives in isolation. Still, the Conditioned Fundamentalist contends that this is because, in the structure of the complex collective, all the components behave differently. The behaviour of every individual component still is completely accounted for by its interactions with other components. For both Simple and Conditioned Fundamentalism, it holds that every level is determinatively complete, i.e. every individual component's behaviour is fully accounted for on the same level.

The collective propensities observed at higher scales are not influencing the behaviour of a single component that realises it. The natural laws[23] holding at one level are complete and higher level laws play no role in lower level processes. Applying parsimony reasoning, it is agreed that components are the only entities that exist; a collective is just the combination of them and nothing extra.

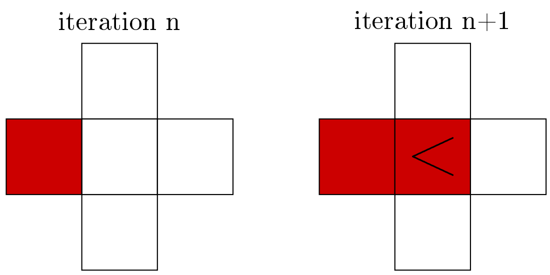
Scientific emergentism challenges this view. It agrees with the idea that aggregation is conditioned, but defies the thought that collective propensities have no role in it.

In what follows, I will assess in more depth how it is possible to be a scientific reductionist and still contend that the higher-level sciences are indispensable. After this argument has been laid out, I will assess the scientific emergentist's idea that in order to have influence of higher levels, the level under consideration cannot be determinatively complete.

2.4 Scientific Reductionism

First, I would like to clarify the stance of the Simple Fundamentalist by means of an example of a cellular automaton that can be used to solve a maze.[24] I choose this example because it is relatively easy to understand and still shows adequately how complex collectives can emerge from simple components. Intuitively put, the algorithm works as follows: There is a grid of n by n cells. For every cell the following rules hold:

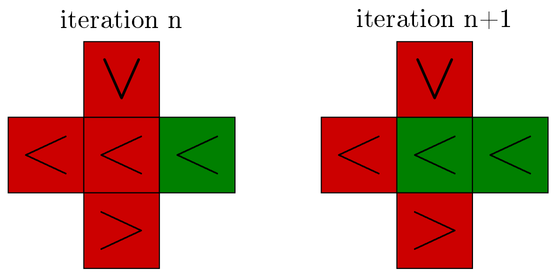
1. If a cell is white and one of the neighbours is red, it will turn red and add a backpointer to the red neighbour.



[23] I will attempt to characterize what I mean by laws and dispositions in the last chapter.

[24] The model that I used for the pictures in the below was programmed for an assignment of the course *Inleiding Adaptieve Systemen*, taught by Gerard Vreeswijk at *Universiteit Utrecht*. I made it in *Netlogo* in collaboration with Aart de Jong.

2. If a cell is red and one of the neighbours is green and has a backpointer pointing to the cell under consideration it will turn green.



2 special cells:

3. Starting cell: starts red.

4. End cell: will become green when one of its neighbours is red.

5. In all other cases, nothing happens.

In the end (Figure 2), every change in every individual cell is completely accounted for by the interactions with its direct neighbours. In that way, the maze is determinatively complete. Using parsimony reasoning the Fundamentalist would state that in this case the process involves n^2 entities (the cells of the maze) and not $n^2 + 1$ (the cells of the maze and the maze itself). An interesting question concerning the position of higher-level sciences would now be "Are descriptions of the marking of the shortest path through the maze reducible to descriptions of the single cells and their interactions?". What grounds does the scientific reductionist have, to refrain from a positive reply?

2.4.1 Explanatory Relevance of Macro Models in Scientific Reductionism

In the first section it was claimed that different models are required to answer different kind of questions. I do not need to refer to the maze, its paths and walls to explain why every cell does what it does. From that it does not follow, however, that these concepts are superfluous in everything I can explain about the maze. The maze is solved if there is a line of green cells between my special start and finish cells, but this would be an incomplete description of what it is for a maze to be solved.

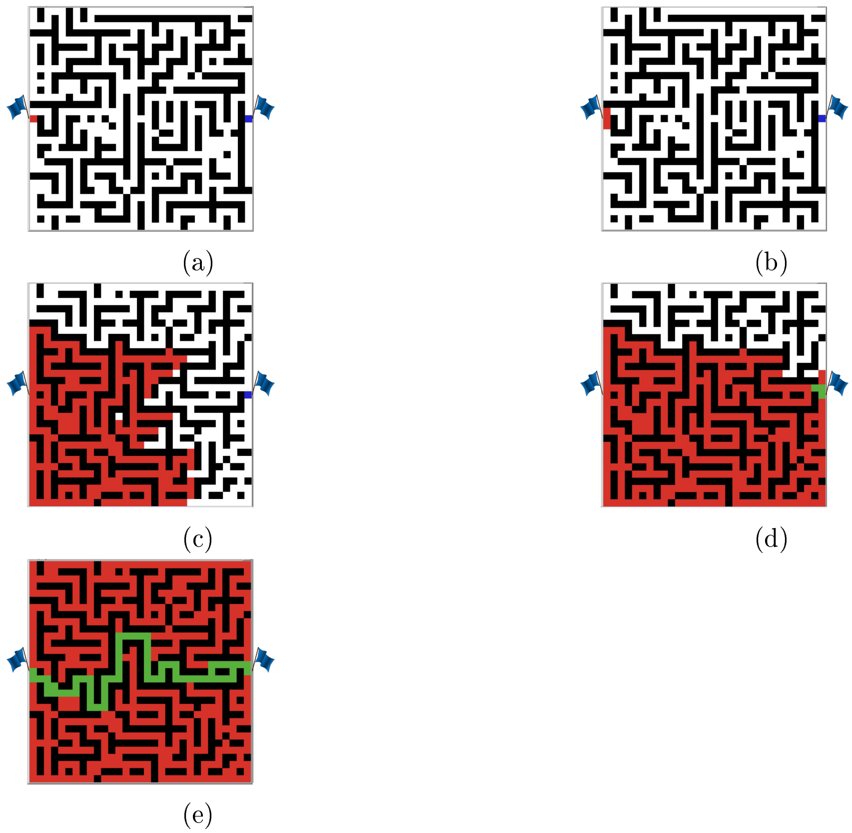


Figure 2: The result of the combination of the rules. The shortest path between Start and Finish is marked. Here the process is shown in steps of about 40 iterations

The solving of the maze could be realised by a large variety of different components. Whether the maze is solved is not only depending on the properties of the individual cells, but also on our identification of the maze as a puzzle with a certain solution. For that, I do need to recognise my set of cells as a maze and identify the walls and the paths that are formed by the cells. We can individuate the walls and the paths by identifying that they have a separate role in the process that is studied. In this particular example, the walls and the paths are realised by simple cells, but one can imagine a plurality of different materials that could realise the same maze, the same relations between walls and paths in so far as these are relevant to the solution. This homogeneity is something that is found in the total composition of these different realisations. The maze is also epistemologically non-reductive in the sense that there are no general type reduction rules from a maze to the parts, the same type of maze can be constructed from different components.

The other way around too, a process can be epistemologically non-reductive for different reasons. If I know the starting state of a component and its direct neighbours, it is not always possible to predict what the situation will look like in the next step. In flocking behaviour of birds for example, if I look at one bird and its direct neighbours and have all the rules that every individual bird follows, I still need to know what the neighbours of the neighbours of this bird are doing in order to know how they will behave in the next step, so that I can deduce what my bird under observation will have to do. In the end I need to take the total swarm of birds into account, that is all the neighbours and all their interactions, to be able to simulate the next step of only one bird in this swarm. Knowledge of the structure of the whole set of individual birds is needed. Just knowledge of a small part of them, does not suffice to model their proceeding behaviour for all the upcoming steps. Only if it is known where all the other birds are in the starting position, I can know what the few birds I am studying will be doing next.

Furthermore, recognizing compositional explanation as central to the sciences, also involves recognising that scientists typically try to explain interlevel relations. They try to explain how higher level composed patterns, can be realised by their components. That a maze can be studied by studying its components does not mean that it cannot be approached as a maze just as well as it can be approached as a set of simple cells. Although scientific reductionists eliminate the idea of a higher-level entity as an entity that exists separate from its parts, they still seek to understand this higher-level entity as a composition of the parts. Voltage sensitive gates for example, in neuroscience, are understood to have the property of being sensitive to voltage. Stating this could result in a true predicate about voltage sensitive gates. Still, this property is realised by the ion channels that constitute it.

Scientists can start at the macro-scale and then analyse how the collectives found at this scale are constituted[25]. Compositional Explanations have a form where the collective is the explanans and the components and their interactions form the explanandum. Eliminating either of them would leave the Compositional Explanation with either an explanation of nothing, or a thing that remains unexplained.

The general line of eliminative materialists is that if we can fully explain

[25] Carl Gillett, *Reductionism and Emergence in Science and Philosophy,* 132

something on one scale, we cannot learn anything new when looking at the same thing on a different scale, nor does it make sense to want to talk in terms of what we see at a different scale. What we can still learn, however, is how to relate what we observe at one scale to what we observe at another. In order to describe what it is that we are relating to each-other we need terms for both the processes as they are observed on a macro-scale and those observed at a micro-scale. So, assuming we can observe the same processes at different scales with different methods, it still makes sense to employ different words for the processes involved. Models are approximations of natural processes. An approximation of relations between sets of entities can be just as true as an approximation of the relations between the different components, without one excluding the other or the process being overdetermined. The same relations are just modelled on different scales, and it can contribute to our insight of the process to study how these models connect.

Earlier we saw, when discussing Kitcher, that explanations always make phenomena intelligible within the terms of the particular explanatory framework. Since we seek to explain different processes, other entities might play a role. We saw as an example that Brodmann divided the areas in the brain based on their cellular structure, while still, to explain a certain information flow in the brain, we might want to make different distinctions, based on the role of the different areas. Does this mean that we're dividing components merely based on pragmatic grounds? Not necessarily, since the areas, that we divide based on role instead of cellular structure, must have collective properties that make them perform this role. Those areas are thus divided based on properties that are observed at a different scale.

Say I have a black and white animation of a waving man displayed on my screen. On a micro-scale, I can describe this whole process in terms of pixels going on and off. This can all be true while the virtual hand is realised by continuously different groups of pixels. There is not one single collective I can refer to while describing the micro-scale process while I am still only referring to one single virtual hand, namely the virtual hand of the virtual man displayed on my screen. This is what I mean by recognising different boundaries at different levels. On a micro-scale, the hand is not recognised as thus, but that does not make it less of a virtual hand. It is just a virtual hand realised by different collectives as it is moving. If I want to link one observation to the other, then I need words for both. Just referring to the micro-scale interactions does not help me much in understanding that it is a virtual hand moving.

When we enquire why something happened, we might enquire after different sorts of reasons. One sort of reason might be the productive process, that includes the physical forces that are involved in process. Scientists today agree that there are only four (possibly three) physical forces; the weak and the strong nuclear forces, the electromagnetic force, and the gravitational force. This does not necessarily mean that every true account of causation will have to mention these forces. Causation is often understood as a concept with a much broader scope. In different theories causation is thought to be identified by means of counterfactuals, interventionist frameworks or other methods. When we are looking for the reason for an action of a person, we might be looking for the considerations of the person involved.

According to the scientific reductionist, those explanations can be complementary and go without excluding one another, because the person exists as a collective of components, with the collective propensity of having considerations. Not always the same collective, yet different collectives realise the same person. The considerations of the person might be the true cause of its action, which in turn exists as a process that is realised by components just as well as the person itself. Still, every component in the process is acting in accordance with the laws of physics, and using a suitable account of causation, one can still denote considerations as the cause of the actions of the person.

2.5 Scientific Emergence

2.5.1 Conditioned Aggregation and Scientific Emergentism

So far, our example of the cellular automaton only clarified the position of the Simple Fundamentalist. To correctly understand the Conditioned Fundamentalist, we'll have to look at the grid on a larger scale. Let's place the example in the middle of a $9n^2$ grid. Something peculiar occurs. Whenever the maze is surrounded by four white neighbours of the same size, the whole maze turns red: hence every single cell in the maze turns red.

The Conditioned Fundamentalist would explain this difference by stating that different rules hold for the cells when they are in a certain composition. Rules that hold for cells in simple collectives in isolation might be different than the rules that hold in larger collectives. This is what Gillett terms the "conditioned view of aggregation".[26]

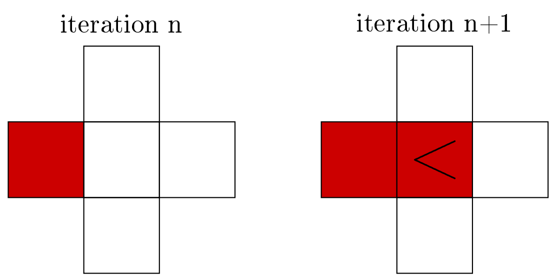
Somehow, according to the Conditioned Fundamentalist, there must be a rule that holds for every individual cell that takes only its direct neighbours into account and that accounts for every cell in the maze turning red. A cell can only behave differently in this composition, because its direct neighbours

[26] Carl Gillett, *Reductionism and Emergence in Science and Philosophy,* 290.

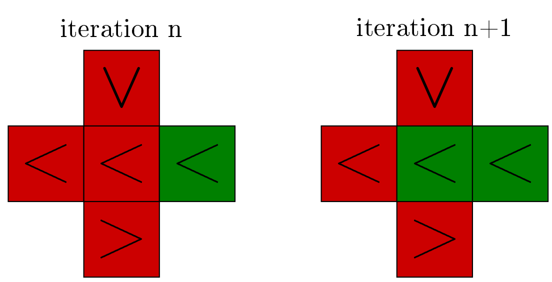
behave differently in this composition. Still, the rules for every individual cell do not need to refer to the composition as a whole, since the whole composition plays no part in the rules for the single cells. As a result, the Parsimony Principle can still be applied: only $4n^2$ entities play a role in the behaviour of every of these individual entities and nothing else.

This modest form of scientific reductionism still leaves something to be challenged. The scientific emergentist has a different explanation of what the situation just described encompasses. Their position is, that in this situation, the behaviour of every individual cell is not fully determined by the interaction with their direct neighbours. The maze changed colour in reaction to its neighbours, because for the composition as a whole, the rule holds that it will turn red when it has four white n^2 neighbours. The properties of the composition as a whole provided for the possibility of this process. For the new situation, according to the scientific emergentist, the following rules hold for every individual cell:

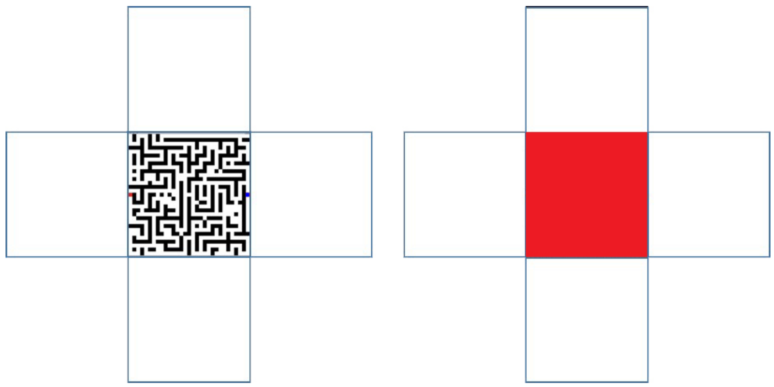
1. If a cell is white and one of the neighbours is red, it will turn red and add an backpointer to the red neighbour.



2. If a cell is red and one of the neighbours is green and has a backpointer pointing to the cell under consideration, it will turn green.



3. If a cell is in a composition that has the property that it will turn red when it has 4 white n^2 neighbours, then it turns red.



2 special cells:

4. Starting cell: starts red.
5. End cell: will become green when one of its neighbours is red.
6. In all other cases, nothing happens.

In the case where the third rule applies, the behaviour of every individual part is not completely determined by the interaction with the direct neighbours, rather it is determined by a property of the compostion as a whole. Gillett terms this position Mutualism. Mutualism subverts the Parsimony Reasoning of the scientific reductionist. If not only the components influence the behaviour of components, but also their composition as a whole, the component level is no longer determinatively complete. Rules that hold at one level might be incomplete when not supplemented with rules that hold at higher levels. This is a very interesting, yet extremely complex position. How are we to think of this 'influence'? If we have only four (possibly three) physical forces, as stated earlier, how then is there room for a whole to somehow influence its parts?

Again, the idea central to the sciences, Compositional Explanation, needs to be consulted. Once again, we are reminded that the components are not separate from the parts, there is no influence between them as if we talk about two billiard balls, one subject to the force applied by the other. The point is that, if components in a certain composition can realise a collective with certain collective novel properties, different rules or laws may apply to these novel properties. These are rules about the behaviour of the collective, but ultimately, because it is realised by components, those rules influence the individual components as well. This is only possible when the laws that hold of components of simpler collectives do not account for all their behaviour. There is some behaviour that only rules for more complex collectives can account for. The scientific emergentist "concludes that 'Nature is regulated not only by a microscopic rule base but by powerful and general principles of organisation.' These new laws, or 'principles of organisation,' cover the novel behaviour and differential powers of the components that compose specific higher-level entities, such as superconductors, magnets, or crystals, which are emergent along with their properties."[27]

2.6 Conclusion

A quick summary before we dive into more complex subject matter: components together realise collectives. Collectives have their own collective properties and follow collective rules. Those rules are also realised by their components and their interactions. So far, we have no problems for the Fundamentalist position. But, then the Mutualist says that the rules that hold for the collective result in a certain behaviour of the collective, and thus the parts, while the parts individually lack the rules to fully account for this behaviour. To prove the Mutualist position, we thus need a situation in which components show behaviour that does not follow from direct interactions with other components and certain background conditions. Instead, this behaviour must be the result of certain rules that hold for the collective that is nonetheless formed by a set of components.

3 What Are the Implications of Mutualism and What Makes the Position Appealing?

3.1 Introduction

Up until now, we managed to avoid an extensive discussion on how those rules, influence relations and interactions work on an ontological level. However, to explain exactly what Mutualism is and how it differs from Fundamentalism, this can no longer be ignored.

[27]Carl Gillett, *Reductionism and Emergence in Science and Philosophy*, 205

3.2 Rules

First of all, what did we mean by interactions and influence relations so far? And why did we only allow for interactions between direct neighbours to be a part of our Fundamentalist framework? The way I would like to approach these things at this point, is as if entities and collectives of entities can have certain properties that make them disposed to act in a certain way when certain manifestation conditions attain. These kind of dispositions are sometimes called "powers", but as I understand Gillett, his idea of powers seems to be slightly different from the dispositional account I am giving now. The manifestation conditions together with the disposition, result in the entity acting in a certain way. So, an entity acts the way it does because of the way it is and certain background conditions that apply. With the rules, that I have been talking about so far, I actually meant the set of interactions that result from the combinations of all the different dispositions and manifestation conditions involved. An example of a rule, would be that two oppositely charged particles will always attract each other. The reason why in the Fundamentalist framework only direct neighbours play a role in the rules holding for components, is that I only wanted to take into account interactions that follow from the properties of neighbouring components that are part of the manifestation conditions of the action that the component under consideration consequently performs. A "direct neighbour" could actually be any neighbour that directly has a part in the manifestation of a certain disposition of the entity. What I mean by direct, is that this is not mediated by additional entities "between" the neighbour and the entity under concern. In case it is, I think that the Fundamentalist would say that only the entity, that the entity under concern has unmediated interaction with, is important for its actions.

3.3 Determinative Completeness

A level is determinatively complete, in my understanding, when all the changes on this level are a result of the sort of local, direct rules we saw in the example of the cellular automaton before we added the extra rule. All that is needed for everything to happen as it happens, are the dispositions of the individual components at one level and their manifestation conditions. Indeed, the dispositions of the structures formed on a macro-scale, are then not relevant for all the changes occurring on the component scale, because those dispositions are already accounted for on the component scale. This does not mean, however, that representations of a process referring to dispositions of whole structures are superfluous, since on their own scale, even if their influence relation is in fact a relation between collectives, there still is an influence relation. Moreover, actions of collectives on a macro-scale, still follow from the dispositions of the collective plus the manifestation conditions defined on the collective scale, yet those dispositions can also be seen as a set of individual dispositions when observed at a smaller scale.

The incredibly interesting idea that Mutualism explores, is that complete structures can have novel dispositions with manifestation conditions, that are not the set of the manifestation conditions of the components. As a result, local manifestation conditions and direct interactions are no longer the only things that account for all the behaviour of the components. Rules holding for total structures also determine the behaviour of the components. This is the crucial difference between the Fundamentalist and the Mutualist: under the Mutualist view, different scales are no longer determinatively complete. Collectives follow rules in agreement with the properties of the collective and components follow rules in agreement with the properties of the components. Although the components realise the collective, the components are additionally influenced the properties of the collective, in the sense that they now obey the higher-level rules of the realised collective.

3.4 Machretic Determination

Determination would then be a relation that does not only relate two entities at the same level, but also relates a structure and the components of this structure. Gillett calls this kind of determination machretic determination.[28] It can only exist if there is no lower level that is determinatively complete. If there is, machretic determination accounts for no additional changes and must be eliminated following parsimony reasoning.

But then again, machretic determination accounts only for differential powers of the parts, i.e. the different dispositions they have in different compositions. This leaves me wondering; is it possible to see the emergent rules as a background conditions and still contend that the rules at one level are determinatively complete?

I like to think of my bicycle as an example. All of its functionalities can be explained by referring to the parts and their direct interactions. However, the fact that it moves more frequently between my house and the Uithof than it goes anywhere else, could perhaps be expressed in a rule concerning me, the bicycle and other entities (including institutions like a university)

[28]Carl Gillett, *Reductionism and Emergence in Science and Philosophy*, 18.

involved. Laws holding for the bicycle and its parts might not be completely accounting for this particular aspect of their behaviour, but if we add in all the physical rules holding for all the components in its environment that collectively compose this process, though this might be very impractical or even impossible to do for us, all those laws and components together might still completely account for the behaviour of the bicycle.

We run into trouble, however, if we apply the same approach to the maze. If we add as a background condition to the behaviour of individual cells that some rules hold in a particular composition of all the cells, then we have to refer to all the cells and hence to the composition as whole. It seems as if there are no rules of the cells themselves that make them do what they do, when those rules can only refer to direct neighbours. While in the bicycle example we could, with some effort, imagine it all to come down to a big chain reaction from component to component, requiring nothing else than their own simple rules. In the example of the maze, when it includes the additional rule that applies to n^2 compositions, this very idea is stipulated to be impossible. The third rule: "If a cell is in a composition that has the property that it will turn red when it has 4 white n^2 neighbours, then it turns red" (Figure 3) is explicitly said not to result from a chain reaction between individual components, but from interaction of collective properties. Without this complicating extra rule, cells already have the means to turn red, that is, when correctly stimulated by their direct neighbours. However, in the last rule, looking only at the cells, they seem to spontaneously turn red. If it was a real natural process, we would want to know how such a change is possible without any apparent energy-transfer. If we allow in our cellular automata universe for n^2 squares to behave as cells themselves, this spontaneous action can be accounted for, there was an energy transfer between several n^2 squares in total, making up the balance.

3.5 Further Discussion on Mutualism

So, what exactly is the problem we are left with? We have said that there are only four fundamental forces. The weak and strong nuclear force, electromagnetic force and gravitational force. In the end, fundamental interactions between particles are just thought to be mediated by one or more of these forces. Particles don't move out of the blue, without a force being applied. Then, why would it be too hasty to conclude that all we need are fundamental, direct interactions to account for all the behaviour of those particles? The point is that certain interactions might only take place, when certain bonds are formed. Structures and combinations of structures might be required for

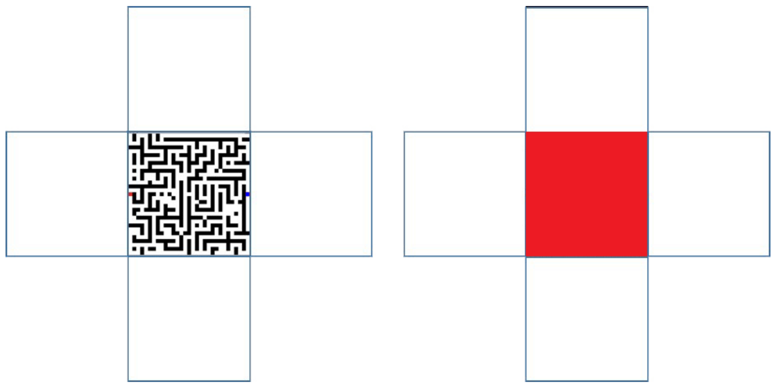


Figure 3: Third rule

certain reactions to take place. Determination is then not an interaction that requires a force, it is more subtly the relation between a manifestation condition and a disposition. Does the condition only involve direct neighbours? Then we have Fundamentalism. Does it involve whole structures? Then we have Mutualism. 'Determinative completeness' means allowing only direct neighbours to be in the conditions. 'Determinative incompleteness' means that whole structures need to be included in manifestation conditions. Do we need extra forces in the last case? No, but finding out how a particle will react on a force that is applied to it, and thus what disposition will manifest, can be more complex in the last case than in the former. In order to find this out we have to include more information about the complete structure and its rules for interaction, instead of only information about the direct neighbours involved.

One way to establish an argument for Fundamentalism would be to argue that there is determinative completeness on the most fundamental level. Papineau attempts to show that at least for some of the workings of the human mind, there can be a complete explanation in physical terms.[29] He concludes that "the argument from physiology can be viewed as clinching the case for the completeness of physics against the background provided by the argument from fundamental forces."[30] He means to say that, because there can be a complete account of the mind where no other forces than the four fundamental ones play a role, there is no emergence in this case.

[29]David Papineau, *Thinking about Conciousness* (New York: Oxford University Press, 2002)

[30]David Papineau, *Thinking about Conciousness*, 253-254.

But, let's go back to what we discovered earlier. Emergentism does not require an extra force. The way in which rules for the complete structure influence the parts of the structure, is different from the way in which the individual parts interact. As we said before, the structure just becomes an additional condition that needs to be included in the rules of the parts in order to know which disposition will manifest. There is no extra force, it is just that the terms that determine what behaviour will occur are more complex than in Fundamentalism. They include information about the total structure, instead of only the properties of the individual particles. Hence, even if physics shows to be complete, there is still room for determinative incompleteness as we formulated it.

Bickle seeks to argue for Fundamentalism by considering a nascent molecular explanation of the psychological property of spatially remembering a location.[31] He shows how this cognitive phenomenon can be explained in terms of molecular components. Moreover, he discusses the interventions at a molecular level that influence the cognitive behaviour. He concludes, that once we have established the link between molecular interactions and cognitive behaviour, there is nothing left for higher-level sciences to explain. This, however, still does not mean that scientific emergentism does not exist. Even if all cognitive models can be correlated with molecular ones, then still that does not mean that there cannot be determinative incompleteness on the molecular level. For as far as current research goes, molecular biology has not shown to be determinatively complete.

Mutualism has been defended by Wilson and Holldobler by referring to the behaviour of eusocial insects.[32] Wilson and Holldobler observe that ant-colonies are well-organised in a sort of heterarchy. They mean to point out that the properties of the colony affect the individual ants and that the properties of the individual ants affect the colony.[33] They support this claim by stating that foragers adapt their behaviour to the needs of colonies, rather than to their individual hunger.[34] In that sense, the state of the colony's supplies determines their behaviour, and not their individual lacking. The foragers react on the amount of food that is accepted by the group. If

[31] John Bickle, "Reducing Mind to Molecular Pathways," *Synthese* 151 (2006): 411-434

[32] Edward O. Wilson and Bert Holldobler, "Dense Heterarchies and Mass Communication as the Basis of Organization in Ant Colonies," *Trends in Ecology and Evolution* 3 (1988): 65-84.

[33] Wilson and Holldobler, "Dense Heterarchies and Mass Communication as the Basis of Organization in Ant Colonies," 65.

[34] Wilson and Holldobler, "Dense Heterarchies and Mass Communication as the Basis of Organization in Ant Colonies," 66.

a certain kind of food is not fully used by the colony, they switch their emphasis to another kind of food. Even though the individual ants use simple heuristics, complex behaviour emerges. Unfortunately for the Mutualist, this example isn't decisive in our debate. Still, the individual ants are the only things that productively interact. The food stores can be seen as being at the same level as the ants. Interactions at a lower level, for example between particular storer ants and various food stores, can affect the food exchange between foragers and the storers in the way that was explained in the above. If, additionally, it can be shown that these lower level interactions account for all the behaviour of the individual ants and the lower level is thus determinatively complete, the Fundamentalist hypothesis can still be true and the behaviour of the ants does not provide us with a counterexample.

3.6 Conclusion

If we assume that collectives follow rules in agreement with the properties of the collective and components follow rules in agreement with the properties of the components, we can see why the Mutualist position seems appealing: total structures have different properties than individual components, these properties might follow their own rules that are not simple aggregations of the components' rules. Yet, questions remain about how this ought to work. I proposed that it might be that, in the Mutualist framework, the manifestation conditions of certain dispositions of the particles include total structures. Determinative incompleteness would then be the situation in which manifestation conditions include more than the dispositions of individual components.

The crucial point in the discussion comes down to either proving that there is one fundamental level that is determinatively complete or finding a counterexample that shows that there are cases in which local interactions cannot account for all of the behaviour of the components of a certain system or process. If we understand the components of a system or process as having certain dispositions and certain conditions under which these dispositions manifest, then it is not a valid critique to state that Mutualism needs an extra force. Mutualism, in this understanding, maintains that the total state of a system or process can sometimes be included in the manifestation conditions of the dispositions of its components. Still, only the fundamental forces act on the components. Yet, what dispositions become manifest is not only dependent on their individual state, but on the total state of the system as well. Arguments in favour of Mutualism, however, are prone to a failure to show that the total structure really has to be included in the manifestation conditions of the dispositions of the individual components.

It appears that there still is a lot of research on determinative completeness to be done, before we are able to conclude that either Mutualism or Fundamentalism is right.

Conclusion

First, I outlined an understanding of scientific modelling. I sketched the idea that, in order to model the world, processes or entities need to be separated so we can specify the relations between them and see how they influence each other. How we individuate different entities or processes and the relations between them might differ, depending on what we want to find out, at what level we observe and how we manipulate what we observe. This can result in different, complementary models of the same process or system. Those models represent different groupings of the same components, resulting in a representation of different properties and relations depending on how the components are grouped. This is a representational pluralist position.

The question that came up was that, if different models can be complementary and capture different aspects of the same process or system, then how do these different aspects influence each other? Can relations between bigger structures influence the behaviour of the individual components that compose these structures? If this is possible, then how is this possible?

Carl Gillett provided us with a theoretical framework leaving us with two viable positions. Mutualism and Fundamentalism. The crucial difference between the two, comes down to whether determinative completeness exists or not. When it does, local rules at the component level can account for all the behaviour of the components. If it does not, something additional has to determine the behaviour of the components.

If we assume that collectives follow rules in agreement with the properties of the collective and components follow rules in agreement with the properties of the components, we can see why the Mutualist position seems appealing: total structures have different properties than individual components, these properties might follow their own rules that are not simple aggregations of the components' rules. Although the components realise the total collective, they are still influenced by it in the sense that it now undergoes the effects of the higher-level rules of the realised collective. There has been critique on the Mutualist position, stating that it seems as if we have to introduce some extra fundamental force, that somehow originates from the total structure and acts on the components.

To show that Mutualism does not need such a thing, I proposed to see the issue as follows: we could say the components of a system or process have certain dispositions and certain conditions under which these dispositions manifest. Mutualism, in this understanding, states that the total state of a system or process can sometimes be included in the manifestation conditions of the dispositions of its components. Still, only the fundamental forces act on the components. Yet, what dispositions become manifest is not only dependent on their individual state, but on the total state of the system as well. Rather than a direct relation between structure and component, there is a relation between different structures that leaves the components no choice but to move along with the whole. Because there is some pressure on the boundaries of the whole, its parts have to move along. Even though, the aggregation of their own dispositions wouldn't lead to this behaviour. Yet, there are no extra forces involved. The components behave differently because of the properties of the whole, but still, the only forces that are applied are the four or three fundamental ones.

Currently, empirical research cannot decide yet on either Mutualism or Fundamentalism. Mutualism has the advantage that it only needs to show that there exists at least one situation in which local rules are not the only rules that affect the components. Fundamentalism has to somehow be able to generalize from individual observations that the fundamental level has to be determinatively complete. Or it can reside in attempts to show for individual cases that there is no influence of the properties of the complete structures on how the individual components behave. This way, it can at least prove for individual cases that machretic determination can not play a role. To conclude, we have seen that a representational pluralist position on scientific models can be maintained, even when there is no scientific emergence. However, it has been shown that this is not a definite reason to reject scientific emergentism.

References

Baddeley, Alan. "The episodic buffer: a new component of working memory?" *Trends in Cognitive Science* 4 (2000):417–423.

Baddeley, Alan, Michael W. Eysenck, and Michael C. Anderson. *Memory.* New York: Psychology Press, 2015.

Bickle, John. *Psychoneural Reduction: the New Wave.* Massachusetts: the MIT Press, 1998.

———. "Reducing Mind to Molecular Pathways." *Synthese* 151 (2006):411–434.

Brodmann, Korbinian. *Brodmann's Localisation in the Cerebral Cortex based on Cytoarchitectures.* 3. Edited by Laurence J. Garey. Translated by Laurence J. Garey. New York: Springer Science+Business Media, Incorporation, 2006.

Cartwright, Nancy. *Nancy Cartwright's Philosophy of Science.* Routledge studies in the philosophy of science. Edited by Luc Bovens and Stephan Hartmann, Carl Hoefer. New York: Routledge, 2008.

Dennett, Daniel C. "Real Patterns." *The Journal of Philosophy* 88 (1991):27–51.

———. "Why the Law of Effect Will not Go Away." *Journal of the Theory of Social Behavior*, vol. 80 (1975).

Dupré, John. *Processes of Life: Essays in the Philosophy of Biology.* Oxford: Oxford University Press, 2012.

Gillett, Carl. *Reduction and Emergence in Science and Philosophy.* New York: Cambridge University Press, 2016.

———. "Strong Emergence as a Defence of Non-Reductive Physicalism: A Physicalist Metaphysics for 'Downward'Determination." *Principia* 6 (2002):89–120.

Kim, Jaegwon. "Emergence Core Ideas and Issues." *New Perspectives on Reduction and Emergence in Physics, Biology and Psychology* 151 (2006):547–559.

Kitcher, Philip. "1953 and all That. A Tale of Two Sciences." *The Philosophical Review* 93 (1975):352–353.

Lycan, William C. *Conciousness.* Massachusetts: the MIT Press, 1995.

Marr, David. "The Philosophy and the Approach." In *A Computational Investigation into the Human Representation and Processing of Visual Information*, 8–38. San Francisco: W.H. Freeman and Company, 1982.

Minsky, Marvin. *Society of Mind*. London: Pan Books Limited, 1988.

Newell, Allen. *Unified Theories of Cognition*. Massachusetts: Harvard University Press, 1990.

Oberauer, Klaus, and Laura Hein. "Attention to Information in Working Memory." *Current Directions in Psychological Science* 21 (2012):547–559.

O'Connor, Timothy, and Hong Yu Wong. "Emergent Properties." In *The Stanford Encyclopedia of Philosophy*, edited by Edward N. Zalta. 2015. Accessed June 16, 2017. plato.stanford.edu/archives/sum2015/entries/properties-emergent.

Papineau, David. *Thinking about Conciousness*. New York: Oxford University Press, 2002.

Reynolds, Craig W. "Flocks, Herds, and Schools:." *Computer Graphics*, vol. 21 (1987).

van Westen, Allert. "Powers, Manifestations, and their Essences." M.A. thesis, Universiteit Utrecht, 2017.

Wilson, Edward O., and Bert Holldobler. "Dense Heterarchies and Mass Communication as the Basis of Organization in Ant Colonies." *Trends in Ecology and Evolution* 3 (1988):65–84.

Wimsatt, William C. *Re-engineering Philosophy for Limited Beings: Piecewise Approximations to Reality*. Massachusetts: Harvard University Press, 2007.

Yalowitz, Steven. "Anomalous Monism." In *The Stanford Encyclopedia of Philosophy*, edited by Edward N. Zalta. 2014. Accessed June 16, 2017. plato.stanford.edu/archives/win2014/entries/anomalous-monism.

VERKLARING KENNISNEMING REGELS M.B.T. PLAGIAAT

Fraude en plagiaat

Wetenschappelijke integriteit vormt de basis van het academisch bedrijf. De Universiteit Utrecht vat iedere vorm van wetenschappelijke misleiding daarom op als een zeer ernstig vergrijp. De Universiteit Utrecht verwacht dat elke student de normen en waarden inzake wetenschappelijke integriteit kent en in acht neemt.

De belangrijkste vormen van misleiding die deze integriteit aantasten zijn fraude en plagiaat. Plagiaat is het overnemen van andermans werk zonder behoorlijke verwijzing en is een vorm van fraude. Hieronder volgt nadere uitleg wat er onder fraude en plagiaat wordt verstaan en een aantal concrete voorbeelden daarvan. Let wel: dit is geen uitputtende lijst!

Bij constatering van fraude of plagiaat kan de examencommissie van de opleiding sancties opleggen. De sterkste sanctie die de examencommissie kan opleggen is het indienen van een verzoek aan het College van Bestuur om een student van de opleiding te laten verwijderen.

Plagiaat

Plagiaat is het overnemen van stukken, gedachten, redeneringen van anderen en deze laten doorgaan voor eigen werk. Je moet altijd nauwkeurig aangeven aan wie ideeën en inzichten zijn ontleend, en voortdurend bedacht zijn op het verschil tussen citeren, parafraseren en plagiëren. Niet alleen bij het gebruik van gedrukte bronnen, maar zeker ook bij het gebruik van informatie die van het internet wordt gehaald, dien je zorgvuldig te werk te gaan bij het vermelden van de informatiebronnen.

De volgende zaken worden in elk geval als plagiaat aangemerkt:

- het knippen en plakken van tekst van digitale bronnen zoals encyclopedieën of digitale tijdschriften zonder aanhalingstekens en verwijzing;
- het knippen en plakken van teksten van het internet zonder aanhalingstekens en verwijzing;
- het overnemen van gedrukt materiaal zoals boeken, tijdschriften of encyclopedieën zonder aanhalingstekens en verwijzing;
- het opnemen van een vertaling van bovengenoemde teksten zonder aanhalingstekens en verwijzing;
- het parafraseren van bovengenoemde teksten zonder (deugdelijke) verwijzing: parafrasen moeten als zodanig gemarkeerd zijn (door de tekst uitdrukkelijk te verbinden met de oorspronkelijke auteur in tekst of noot), zodat niet de indruk wordt gewekt dat het gaat om eigen gedachtengoed van de student;
- het overnemen van beeld-, geluids- of testmateriaal van anderen zonder verwijzing en zodoende laten doorgaan voor eigen werk;
- het zonder bronvermelding opnieuw inleveren van eerder door de student gemaakt eigen werk en dit laten doorgaan voor in het kader van de cursus vervaardigd oorspronkelijk werk, tenzij dit in de cursus of door de docent uitdrukkelijk is toegestaan;
- het overnemen van werk van andere studenten en dit laten doorgaan voor eigen werk. Indien dit gebeurt met toestemming van de andere student is de laatste medeplichtig aan plagiaat;
- ook wanneer in een gezamenlijk werkstuk door een van de auteurs plagiaat wordt gepleegd, zijn de andere auteurs medeplichtig aan plagiaat, indien zij hadden kunnen of moeten weten dat de ander plagiaat pleegde;
- het indienen van werkstukken die verworven zijn van een commerciële instelling (zoals een internetsite met uittreksels of papers) of die al dan niet tegen betaling door iemand anders zijn geschreven.

De plagiaatregels gelden ook voor concepten van papers of (hoofdstukken van) scripties die voor feedback aan een docent worden toegezonden, voorzover de mogelijkheid voor het insturen van concepten en het krijgen van feedback in de cursushandleiding of scriptieregeling is vermeld.

In de Onderwijs- en Examenregeling (artikel 5.15) is vastgelegd wat de formele gang van zaken is als er een vermoeden van fraude/plagiaat is, en welke sancties er opgelegd kunnen worden.

Onwetendheid is geen excuus. Je bent verantwoordelijk voor je eigen gedrag. De Universiteit Utrecht gaat ervan uit dat je weet wat fraude en plagiaat zijn. Van haar kant zorgt de Universiteit Utrecht ervoor dat je zo vroeg mogelijk in je opleiding de principes van wetenschapsbeoefening bijgebracht krijgt en op de hoogte wordt gebracht van wat de instelling als fraude en plagiaat beschouwt, zodat je weet aan welke normen je je moeten houden.

Hierbij verklaar ik bovenstaande tekst gelezen en begrepen te hebben.
Naam: Fleur Petit Studentnummer: 5583837
Datum en handtekening: 24-08-2017

Dit formulier lever je bij je begeleider in als je start met je bacheloreindwerkstuk of je master scriptie.

Het niet indienen of ondertekenen van het formulier betekent overigens niet dat er geen sancties kunnen worden genomen als blijkt dat er sprake is van plagiaat in het werkstuk.