

Singular Compositional Explanations

Special Cases

The core methodological proposal from Chapter 1 is that, if historians and philosophers of science are to understand how scientists try to confirm compositional hypotheses, there is value in looking closely at the reasons they present in the recent experimental scientific literature. This chapter begins to show some of the consequences of this methodological proposal. More specifically, it shows that scientific explanatory practice is more complicated than is captured by the relatively simple theory of singular compositional explanation sketched in Chapter 2. A descriptively accurate account of scientific explanatory practices has to include more details.

Here, I do not aspire to complete a list of scientific compositional explanations. Instead, I provide the bare minimum for addressing the range of compositional abductive inferences I think are to be found in the case studies in Chapters 5 and 6. Here, I envision three additions. Section 3.1 discusses the explanation of rates of activities of wholes. Section 3.2 considers the explanation of experimental results. The point of this section is to connect the theory of singular compositional explanation introduced in Chapter 2 to the context of experimental results. Consequently, one should see why the theory of singular compositional explanation is the way it is: it is to articulate what is sometimes involved in the explanation of results. Section 3.3 will introduce the idea of explaining the results of controlled experiments. Section 3.4 will draw together the elements from this chapter in an illustration of the explanation of controlled experiments involving rates of activity instances.

3.1 Explaining Rates

In Chapter 2, I proposed that one difference between activity instances and property instances is that activity instances take place at rates, whereas property instances do not. Based on this feature, a neuron's resting potential counts as a property instance since it has no rate. In contrast,

the action potential at a time has a specific value, say, -60 mV, but it also has a rate of change. Based on this feature, the action potential counts as an activity instance. Of course, at maxima and minima, the action potential has a rate of change of 0 mV/msec, but that is still a rate. Further, to be clear, the resting potential can change, and the change (either at an instant or over some interval) will have a rate, say, +1 mV/msec. However, a change in a resting potential is an activity instance, so it should have a rate. So, there must be a distinction between a resting potential and a change in a resting potential.

Given that activity instances have rates, one might expect that scientists sometimes take an interest in explaining those rates. They want to explain why things happen at the rate they do. Consider, for example, exponential growth and decay. Why did this population of bacteria increase in number exponentially? Because the individual bacteria reproduced in proportion to their numbers. Why did the radioactivity of this sample of U^{238} decrease exponentially? Because the individual atoms decayed in proportion to their numbers. Linear growth and decay occur when the same number of occurrences takes place per unit time. Why did the number of rings in this tree increase linearly? The tree added one ring per year. Why did the soil along this river erode linearly? Each year the same amount of soil was removed.

Of course, not all explanations of rates are grouped by their rates. Consider a more specific and concrete example. In a discussion of an experimental result in 1949, Hodgkin and Katz implicitly asked themselves, “Why did the action potential of this axon rise at the rate it did?” They answered that, “Our hypothesis therefore suggests that the rate of rise of the action potential should be determined by the rate of entry of sodium” (Hodgkin & Katz, 1949a, p. 55).¹ They believed they could explain the rate of rise of the action potential in terms of the number of sodium ions entering the axon. I will examine this example in greater detail in Section 3.4. Chapter 5 will contextualize this example with further details of Hodgkin and Katz’s paper that reveal that they were very concerned with the rates at which the action potential rises and falls.

Consider further examples of the explanation of rates far removed from neuroscience. There is an enormous literature on multiple aspects of human aging that focuses on rates of decline. For example, exercise scientists are very interested in changes in performance and rates of change

¹ See Brown (2020, p. 28f) for additional exposition.

in performance with aging.² Regarding track and field performance Baker et al. (2003) report that

There were significant differences in the rates of percentage decline in running events over various distances for both males and females . . . There were no differences in rates of declining function for any of the walking events . . . The strength-dependent throwing events and pole vault showed the greatest rates of decline with age. (Baker et al., 2003, p. 47)

Given the many examples of scientific efforts to explain the rates of activities, it is surprising that there has been so little New Mechanist attention to the topic.

There is much to be said about the explanation of rates. For present purposes, however, I will only introduce one set of explanations of the rates of activity instances. I believe there are others. The proposal here is that scientists sometimes explain the rate of some activity instance of an individual – the rate of an S Ψ -ing – by appealing to the number of activity instances of its parts – the number of x_i 's ϕ_i -ing. Thus, Hodgkin and Katz explained the initial rate of rise of the action potential in terms of the numbers of sodium ions entering the axon. In another example to be discussed in Chapter 5, Richard Keynes explained the exponential decay in the radioactivity of axons in terms of the number of radioactively labeled potassium ions diffusing out of the axon.

Note that this account of the explanation of rates meshes well with the proposal that scientists sometimes take an interest in spatiotemporal particulars. If Hodgkin and Huxley explained the rate of rise of the action potential in terms of the number of sodium ions entering the axon, then they must have been interested in the individual sodium ions entering the axon. This interest does not, of course, take the form of their being concerned with the individual identities of the individual sodium ions. Instead, the idea is that they had to have some interest in the number of individual sodium ions moving into the axon.

3.2 Interpreting Experimental Results

Sometimes scientists write about the interpretation of experimental results. Sometimes they write about what experimental results mean or what is going on in an experiment. Here, I wish to provide an account of these

² See, for example, Moore (1975), Schulz and Curnow (1988), Hollings et al. (2014), and Haugen et al. (2018).

informal locutions. I characterize what scientists are sometimes doing when they interpret experimental results: they are giving singular compositional explanations.

To begin, I distinguish between data and results. Borrowing from James Bogen and James Woodward, I propose that data are what register on measuring devices, such as oscilloscopes.³ By contrast, results are things in the world scientists are trying to measure, such as action potentials or axonal currents. The term “data targets” might provide a more helpful description of what I have in mind than does “results,” but at least some scientists sometimes use “results” in the way I propose. Results differ from what Bogen and Woodward mean by “phenomena” insofar as the former, but not the latter, are spatiotemporal particulars.

To flesh out this distinction, let me begin with a more detailed exposition of what Bogen and Woodward mean by “data.” They write,

As a rough approximation, data are what registers [sic] on a measurement or recording device in a form which is accessible to the human perceptual system, and to public inspection. (Woodward, 1989, p. 394)

Examples of data include bubble chamber photographs, patterns of discharge in electronic particle detectors and records of reaction times and error rates in various psychological experiments. (Bogen & Woodward, 1988, p. 306, cf., pp. 311, 316–317)⁴

Many mid-century oscilloscope recordings of axonal activity instances fit nicely within the characterization Bogen and Woodward offer. Moreover, the example of oscilloscope traces is on par with the example of bubble chamber photographs. Both of these present measurements or recordings that are accessible to public inspection and to the human perceptual system.

Bogen and Woodward also propose that “Data are . . . idiosyncratic to particular experimental contexts, and typically cannot occur outside of those contexts” (Bogen & Woodward, 1988, p. 317). Further, “many different sorts of causal factors play a role in the production of any given bit of data, and the characteristics of such items are heavily dependent on the peculiarities of the particular experimental design, detection device, or data-gathering procedures an investigator employs. Data are, as we shall say, idiosyncratic to particular experimental contexts, and typically cannot occur outside of those contexts” (Bogen & Woodward, 1988, p. 317).

³ Bogen and Woodward (1988).

⁴ See also Woodward (1989, p. 394).

Research on the action potential nicely illustrates the idiosyncrasy of data. Hodgkin and Huxley (1939) reported on experiments performed at the Laboratory of the Marine Biological Association in Plymouth, UK. Their experiments generated data on the action potentials in giant axons isolated from *Loligo forbesi* recorded using a microelectrode made from a glass tube, filled with seawater, to which was attached a silver wire coated with silver chloride at the tip. Kenneth Cole and Howard Curtis performed somewhat different experiments at the Marine Biological Laboratory at Woods Hole, MA.⁵ Their experiments generated data on the action potential in giant axons isolated from *Loligo pealii* recorded using pulled glass microelectrodes filled with KCl isosmotic with seawater. Hodgkin and Huxley used one species of squid, whereas Curtis and Cole used another. Hodgkin and Huxley used microelectrodes of one design, whereas Curtis and Cole used those of another.

Tolman's work on rat maze navigation illustrates the idiosyncrasy of data as well. Tolman (1948) reported the results of several "latent learning" experiments involving mazes of various designs. Blodgett (1929) had rats run a six-unit T-maze for a food reward, plotting error scores over multiple days of testing. Tolman and Honzik (1930) ran a fourteen-unit version of this experiment. Spence and Lippitt (1946) performed a Y-maze experiment in which rats chose between an arm with food and an arm with water.

Turn now from Bogen and Woodward's concept of data to their concept of phenomena. Woodward explains that,

Phenomena, as I shall use the term, are relatively stable and general features of the world which are potential objects of explanation and prediction by general theory. Examples of real or putative phenomena, some of which will be discussed in more detail below, include weak neutral currents, gravitational radiation, Brownian motion, proton decay, capacity limitations and recency effects in short term memory, and the proportionately higher rate of technical innovation among middle-sized firms in moderately concentrated industries. (Woodward, 1989, p. 393)

One of the significant differences between data and phenomena is that, whereas data are supposed to be idiosyncratic to specific experimental contexts, phenomena are not. Phenomena are supposed to be "general features of the world."

I have not reviewed Bogen and Woodward on data and phenomena simply to take that framework on board. Instead, I use it to set the stage for

⁵ See Curtis and Cole (1942).

articulating a slightly different picture. First of all, I propose to go beyond the idea that data are idiosyncratic to experimental contexts, such as Hodgkin and Huxley's lab at the Marine Biological Station at Plymouth. I propose, in addition, that data, as I intend them, are spatiotemporal particulars. They are individual measurements of, say, action potentials, that occur at specifiable times and places. To propose that data are spatiotemporal particulars is to go beyond proposing that they are idiosyncratic, since one might hold data are idiosyncratic types rather than tokens. For what it is worth, Bogen and Woodward might accept this further step, but that is inessential for my purposes. Here, I am specifying what I mean by data so as to provide a descriptively adequate account of the explanation of experimental results.

Second of all, I propose that for each spatiotemporal particular datum, a scientist aims to "hit" a spatiotemporal datum target or result. The idea is that the scientist aims to have one perceptually accessible spatiotemporal particular indicate something about another (typically) perceptually inaccessible spatiotemporal particular. More concretely, an oscilloscope datum might be intended to indicate, say, an action potential. Note that the use of "aims" is meant to allow that a datum may miss its target, as being confounded with other factors. One could put the matter another way: ideally, a single spatiotemporal localizable trace on an oscilloscope indicates a single spatiotemporally localizable action potential; ideally, a single verbal report indicates a single perception of the Hermann grid illusion. My concept of a result differs from what Woodward means by a phenomenon. Whereas my concept of a result is of a spatiotemporal particular, Woodward's concept of a phenomenon is something general.⁶ This is how I understand Woodward's claim that phenomena are general features of the world. I do not reject his concept of a phenomenon. Instead, I am proposing another concept.

With the idea of a result on the table, it should be clear how the theory of singular compositional explanation dovetails with the concept of a result. In mid-twentieth-century physiology, some data were oscilloscope traces, whereas the results were action potentials. The results, in this case action potentials, were to be singularly compositionally explained in terms of ions fluxes. In the study of the Hermann grid illusion, the data were verbal reports, the results were perceptions and the contributing activity instances of those perceptions (recall Section 2.2.2) were to be singularly

⁶ Paul Teller's concept of token phenomenon might be the same as my concept of a result (Teller, 2010, p. 820f).

compositionally explained in terms of the activity instances of retinal ganglion cells.

Further, the term “result” should be read as broad enough to include individuals, activity instances of individuals, rates of activity instances of individuals, and property instances of individuals. Much as Bogen and Woodward take their concept of phenomena to be ontologically noncommittal, so I take my concept of a result to be ontologically noncommittal.⁷

Before moving on, I need to digress to forestall a potential objection. One might think that Bogen and Woodward’s view is that scientists do not explain data, as they are idiosyncratic, hence that scientists also do not explain results, as they too are idiosyncratic. At times, their writings might suggest this view: “Some versions of the claim that scientific theories explain facts about what we observe amount to the mistaken idea that theories explain facts about data” (Bogen & Woodward, 1988, p. 306) and “In Sections IV and V, we defend the claim that scientific theories explain facts about phenomena rather than data” (Bogen & Woodward, 1988, p. 314). There is, however, reason to think that they do admit that scientists *in some sense* explain data and that they would admit scientists *in some sense* explain results. This involves reading Bogen and Woodward’s texts more carefully, reviewing the arguments they give for these views.

Consider, first, their case for saying that a theory of molecular structure does not explain a particular datum regarding the melting point of a sample of lead:

It is easy to see that a theory of molecular structure which explains why the melting point of lead is approximately 327 degrees could not possibly explain why the actual data-points occurred. The outcome of any given application of a thermometer to a lead sample depends not only on the melting point of lead, but also on its purity, on the workings of the thermometer, on the way in which it was applied and read, on interactions between the initial temperature of the thermometer and that of the sample, and a variety of other background conditions. No single theory could accurately predict or explain an outcome which depends upon the confluence of so many variable and transient factors. (Bogen & Woodward, 1988, pp. 309–310)

The argument is not that *scientists* do not explain data. Nor is it that *science* does not explain data. Nor is it that there is no explanation of data at all. It is that no single theory explains a datum. To explain a datum requires resources beyond the scope of a single scientific theory. That, however, is

⁷ Bogen and Woodward (1988, p. 321).

consistent with there being *some sense* in which scientists explain data/results. It is consistent with there being *some sense* in which there are scientific explanations of data/results.

Second, the arguments Bogen and Woodward give in their Sections IV and V are somewhat different:

Typically, scientific theories are expected to provide (what we shall call) systematic explanations of facts about phenomena rather than facts about data. To show why this is the case, we will briefly describe in this section two features which typical systematic explanations possess. The first has to do with the exhibition of detailed patterns of dependency. The second has to do with unification and systemization. (Bogen & Woodward, 1988, pp. 322–323)

Later, they claim, “it will often not be feasible to provide explanations of data satisfying the requirements on systematic explanation outlined above.” Without going into what I take to be some of the subtle details of what systematic explanations are, the rejoinder is that when scientists explain data or results, they are not *systematically explaining* data or results. I can simply concede that explanations of data and results are not systematic. They are explanatory in another sense. Indeed, in a footnote in section IV, Bogen and Woodward open the door to such a possibility:

In ordinary usage, the identification of a single factor which played a causal role in the production of some outcome is often described as an explanation of that outcome, even when many other factors also played a role in producing the outcome in question, and even when the details of the mechanism by which the identified factor produced the outcome are left vague and unspecified. Let us call such explanations “singular causal explanations.” . . . Our point in introducing the requirements described below is not to challenge this usage. Rather our point is simply that such singular causal explanations differ in important ways from the kind of explanations we describe as “scientific” or “systematic,” and which we intend our requirements to characterize. (Bogen & Woodward, 1988, p. 322, fn. 17)

Bogen and Woodward essentially invite the development of singular causal explanations of data. I have indirectly taken them up on this invitation, insofar as I have developed a theory of singular compositional explanation, not of data, but of results. Moreover, although I will not go into the matter, I can agree with them that singular compositional explanations differ in important ways from the explanations they describe as systematic.

Quite apart from Bogen and Woodward’s view, there is good reason to be open to a theory of singular causal explanation and a theory of singular compositional explanation. I assume that scientists are not “mysterians”

about the production of data or results. Although some data and results may be inexplicable, it is not generally true that scientists take the generation of data or results to be a complete and utter mystery inexplicable by science. Scientists generally believe that data and results are capable of explanation in some sense. My proposal is intended to flesh out the sense in which results are sometimes compositionally explained. Philosophers of science who are not mysterians about results should, therefore, be open to the possibility of singular causal explanation and singular compositional explanation.

3.3 Explaining the Results of Controlled Experiments

Consider now the typical context for the explanation of experimental results, namely, the explanation of the results of controlled experiments. By a “controlled experiment,” I mean, in the simplest case, an experiment involving two sets of conditions that are taken to be the same for a single determinative factor and, possibly, a single determined factor.⁸ Here, I will introduce the topic by way of the different explanation-seeking why-questions that controlled experiments can motivate.

Consider two explanation-seeking why-questions:

1. Why did axon no. 15 in seawater display an initial inward current when depolarized by 65 mV?
2. Why did axon no. 15 *in seawater* display an initial *inward* current when depolarized by 65 mV, but *in a sodium-free medium* display an initial *outward* current when depolarized by 65 mV?⁹

The first of these questions seeks a singular dynamic compositional explanation in which an activity instance of a whole (the inward current of axon no. 15) is explained in terms of activities of parts (the inward movements of sodium ions). The second question – call it a “controlled experiment question” – is obviously more complicated, as it seeks consideration of two distinct sets of conditions. An answer to this second question provides a singular dynamic compositional explanation of the inward current in the sodium-containing medium and a singular dynamic compositional explanation of an outward current in a sodium-free medium. In notation, there is an explanation of an instance of $S \Psi$ -ing in terms of x_i 's ϕ -ing and an

⁸ My sense of “controlled experiments” is the same as that in Schickore (2019). These differ from what she describes as “controlling experiments,” which involve experimentation meant to probe relevant variables.

⁹ One might ask how this question relates to what are commonly called “contrastive questions.” This issue is discussed in Chapter 9 in the context of Lipton's view of IBE.

explanation of an instance of $S \Psi^*$ -ing in terms of x_i 's ϕ^* -ing. Thus, the explanation of the results of a controlled experiment involves what I will loosely describe as an "amalgamation" of considerations beyond what is involved in a singular compositional abduction.¹⁰

As with any proposed philosophical distinction, there is room to debate exactly how to draw the distinction. Whatever one's theory it is important to notice that the compositional explanation of a result of a single experiment is not the same as the explanation of the results of a controlled experiment. Clearly a compositional explanation of $S \Psi$ -ing is not identical to a compositional explanation of $S \Psi$ -ing and $S \Psi^*$ -ing. Further, why-questions like 2) are raised by the results of controlled experiments used to test compositional hypotheses. The target of the distinction is the results of controlled experiments. To see this, return to the first experiment discussed in Hodgkin and Huxley (1952a). Chapter 1 broached the idea that Hodgkin and Huxley used an experiment to make an abductive argument supporting the sodium hypothesis. Now, however, I emphasize an additional detail of their experiment and their argument. In theory, Hodgkin and Huxley might have sought to use a singular dynamic compositional explanation – an answer to question "1" – in order to support the sodium hypothesis. They did not do that. Instead, as noted in Chapter 1, Hodgkin and Huxley performed an experiment in which they measured the current first in a seawater solution, then in a sodium-free solution, then again in a seawater solution. The results of this experiment invite questions like "2." To accurately describe their experiment, one must have something to say about the experimental control.

Hodgkin and Huxley's argument enabled them to convey to their fellow neuroscientists the crux of their thinking, namely, that the 65 mV depolarization somehow changes the membrane permeability. Thus, when the external medium has more sodium than does the axoplasm, sodium rushes in, whereas in a medium with less sodium than in the axoplasm, sodium rushes out. Hodgkin and Huxley's subsequent experiments regarding the sodium hypothesis varied the depolarization and the sodium concentration of the external medium, in essence, tracking how changes in the amount of depolarization and changes in the external sodium concentration affected the membrane current. The results of these experiments raise any number of more specific questions like "2."

Consider another example. Hodgkin and Huxley's second experiment in Hodgkin and Huxley (1952a) included a repetition of the first

¹⁰ Thanks to Caitlin Mace for suggesting the term "amalgamation" to me.

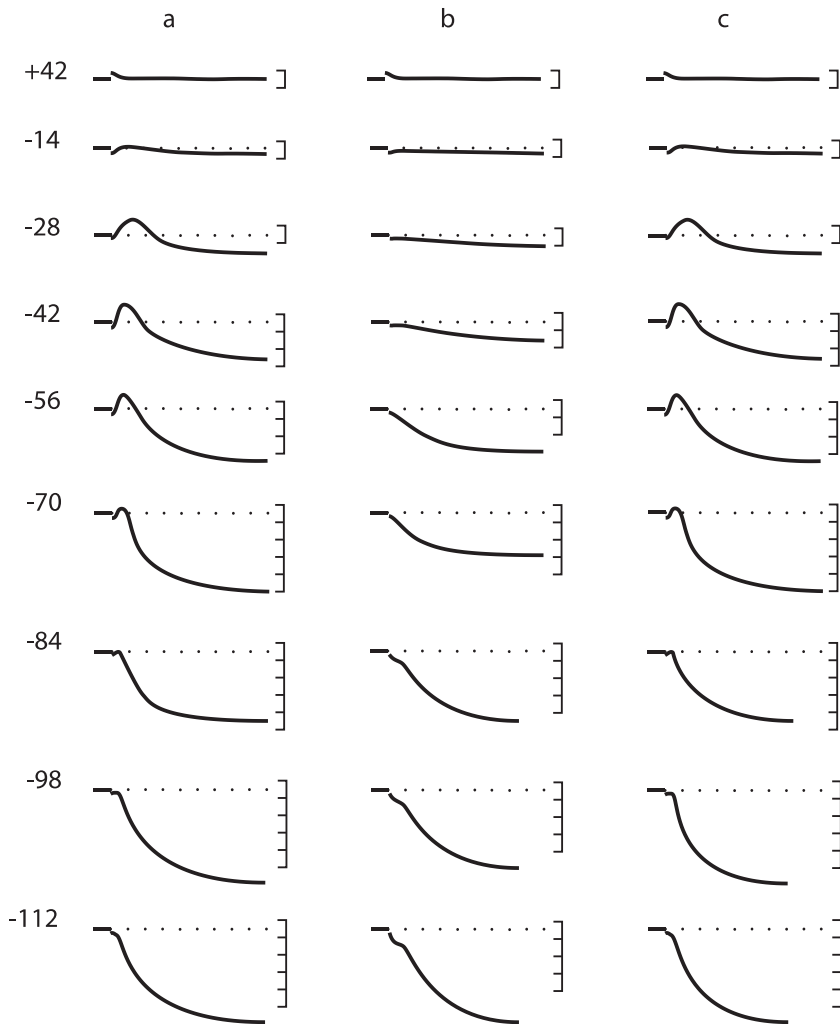


Figure 3.1 Ionic currents in response to different command voltages in sodium-containing (left column, a), sodium-free (middle column, b), and sodium-containing media (right column, c). Vertical scale: 1 division is 0.5 mA/cm^2 . Horizontal scale: interval between dots is 1 msec. Redrawn from Hodgkin and Huxley (1952a, p. 451, figure 2).

experiment and its sodium-containing/sodium-free/sodium-containing protocol, only with the axon voltage-clamped at different values. The second experiment investigates the role of a second variable, the “command voltage” (see Figure 3.1). Whereas Hodgkin and Huxley’s first

experiment involved two singular dynamic compositional explanations, an explanation of an instance of $S \Psi$ -ing and an explanation of an instance of $S \Psi^*$ -ing, the second example involves twenty-seven such explanations, one for each curve in the figure. Thus, this figure invites any number of comparisons, not just between columns of a single row, but also between multiple rows and columns. The figure conveys a lot of information that cries out for explanation. Here again, in order to accurately describe Hodgkin and Huxley's experiment, the historian and philosopher of science must have something to say about experimental control.

3.4 A Controlled Experiment with Rates

As mentioned in Section 3.1, Hodgkin and Katz (1949a) were concerned to explain the rate of rise of the inward current of the action potential. There is now a further detail to add: Hodgkin and Katz performed a controlled experiment that invited explananda that included rates of rise of the action potential. The essence of their experiment lies in tracing changes in an axon's activity over the course of a few minutes following the replacement of the standard sodium-containing medium with a sodium-free medium, then returning the axon to the standard sodium-containing medium. Figure 3.2 illustrates these changes. The solid curves 1–8 represent the action potential before the removal of sodium, along with the changes following the removal of sodium. The dashed lines 9–10 represent the action potential after the return of the sodium medium. Hodgkin and Katz were concerned with two principal features of these curves. First, the peaks of curves 1–8 are different and, second, the less steep slopes of the rising phase of curves 1–8.

Figure 3.2 suggests a complex situation. For one thing, each line corresponds to a distinct singular dynamic compositional explanation. Curve 1 is an activity instance Ψ of the axon S ; curve 2 is a somewhat different activity instance Ψ^* of the axon S ; curve 3 is a somewhat different activity instance Ψ^{**} of the axon S ; and so forth. The singular dynamic compositional explanation of $S \Psi$ -ing implicates one set of individual sodium ions moving into the axon, $\{x_1 \phi\text{-ing}, x_2 \phi\text{-ing}, \dots, x_n \phi\text{-ing}\}$; the singular dynamic compositional explanation of $S \Psi^*$ -ing implicates a distinct set of individual sodium ions moving into the axon, $\{x_1 \phi\text{-ing}, x_2 \phi\text{-ing}, \dots, x_m \phi\text{-ing}\}$; and the singular dynamic compositional explanation of $S \Psi^{**}$ -ing implicates yet another distinct set of individual sodium ions moving into the axon, $\{x_1 \phi\text{-ing}, x_2 \phi\text{-ing}, \dots, x_l \phi\text{-ing}\}$. In the foregoing notation, the different letters in the final subscripts for the

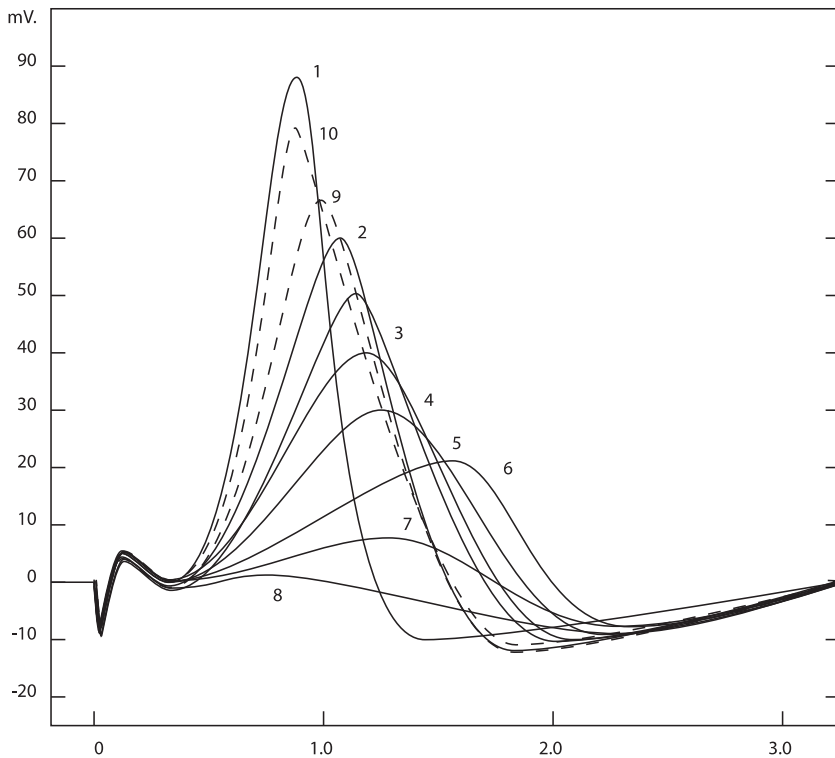


Figure 3.2. Action of isotonic dextrose. Record 1: action potential in sea water just before application of dextrose. 2–8: records taken at following times after arbitrary zero, defined as moment of application of dextrose: 2, 30 sec; 3, 46 sec; 4, 62 sec; 5, 86 sec; 6, 102 sec; 7, 107 sec; 8, 118 sec. Record 9 taken 30 sec after reapplication of sea water; 10, record at 90 and 500 sec after reapplication of sea water (only one curve is drawn since the responses at these times were almost identical).

individuals x are meant to indicate different numbers of ions moving across the membrane. (The notation does nothing, however, to capture the idea that two disjoint sets of ions might cross the membrane.) There is, thus, a set of singular dynamic compositional explanations. The figure clearly invites any number of pairwise comparisons, including the following: Why is the peak potential in curve 1 greater than the peak potential in curve 2? Why is the peak potential in curve 2 greater than the peak potential in curve 3? These are singular dynamic compositional explanations in a controlled experiment, much like that found in the first experiment of Hodgkin and Huxley (1952a). And, of course, the pairwise

comparisons are merely a special case of comparing the members of the set of explanations.

Another facet of the results reported in Figure 3.2 concerns the rates of rise and fall of the action potential. These are represented by the slopes of the curves. Not only are the peaks of curves 2–8 lower than the peak of curve 1, but it also takes longer for the action potentials in 2–8 to reach their respective peaks. The rates of rise are lower. Hodgkin and Huxley propose that “Our hypothesis therefore suggests that the rate of rise of the action potential should be determined by the rate of entry of sodium, and on a simple view it might be expected to be roughly proportional to the external concentration of sodium” (Hodgkin & Katz, 1949a, p. 55). For Hodgkin and Katz, the rate of entry of sodium explains the rate of rise of the action potential. By this, they do not mean that the speeds at which sodium ions enter the cell explains the rate of rise. Instead, the rate of entry refers to the number of sodium ions per unit time that enter the cell. Schematically, the form of the explanation is not the rate of x_i ’s ϕ_i -ing explains the rate of $S \Psi$ -ing. Instead, the idea is that it is the number of x_i ’s ϕ_i -ing that explains the rate of $S \Psi$ -ing. Here is an experiment that demands that historians and philosophers of science recognize that (a) scientists traffic in the explanation of rates and (b) these explanations are sometimes matters of explaining the rate of $S \Psi$ -ing in terms of the number of x_i ’s ϕ_i -ing.

As a final point, note that I do not suppose that there is any intrinsic connection between compositional abduction and experimental results. A scientist might use compositional abduction outside the context of experimental interpretation. For example, Chapter 6 will note that Baumgartner’s introduction of the retinal ganglion cell theory of the Hermann grid illusion involved compositional abduction, but no new experimentation. Moreover, there can be experimental interpretations that do not involve compositional abduction. Causal abduction might play a role. Sometimes experimental interpretations might be limited to enumerative inductions. In a similar fashion, I do not suppose that there is any intrinsic connection between compositional abduction and the interpretation of the results of controlled experiments. Instead, it is merely that, in many cases, the scientific use of compositional abduction takes place in the context of the interpretation of the results of controlled experiments.

3.5 Summary

In this chapter, I have expanded on the compositional explanatory pluralism advanced in Chapter 2. I have proposed that scientists sometimes

explain rates of activities of wholes in terms of the number of activities of associated parts. In addition, I have described cases in which scientists invoke compositional explanations of results, or data targets, that are produced in experiments. I have further proposed that there are explanations that arise from the results of controlled experiments. These explanations may be thought of as families of compositional explanations. I think it would be unsurprising to find that there are still other scientific explanations involving compositional relations, but further search for them would be orthogonal to my focus on compositional abduction. The expanded repertoire of explanations is merely the bare minimum that the historian and philosopher of science needs in order to describe the cases to be discussed in Chapters 5 and 6.