Thinking the Body, from Hegel's Speculative Logic of Measure to Dynamic Systems Theory

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Abstract:
A study of shifts in scientific strategies for measuring the living body, especially in dynamic systems theory: 1) sheds light on Hegel's concept of measure in *The Science of Logic*, and the dialectical transition from categories of being to categories of essence; 2) shows how Hegel's speculative logic anticipates and analyzes key tensions in scientific attempts to measure and conceive the dynamic agency of the body. The study's analysis of the body as having an essentially dynamic identity irreducible to measurement aims to contribute to reconceiving the body, in a way that may be helpful to overcoming dualism.

I am writing this sentence on a pad of paper. The movement of writing seems integral to my thinking, yet the tendency in philosophy of mind and science is to barricade the mind in the head, to trace it from within by reflection, and to identify mindful activity with a special, complex part of the body. In the effort to overcome a dualism that disembodies mind, we have somehow ended up with a mind that lumbers about in an otherwise mindless body-machine, we have ended up 'disminding' the body. I think that it is wrong to 'dismind' the body, that philosophers such as Merleau-Ponty and Dewey have shown that mind is inseparable from the whole of the moving body in the world.[1] Yet we still have difficulty thinking of the whole moving body as mindful. Perhaps we do not see how thinking could belong to living movements, parts and processes that we find in many organisms beside ourselves.

In part the problem is conceptual, and what I want to show is how Hegel's speculative logic can contribute to the enormous conceptual task of learning to think of the whole moving body as mindful. My interlocutor is science, since the empirical work of experimentation has driven contemporary science to rethink the body, for example, to conceive the body as a system that dynamically organizes itself, in which case mindfulness arises in the whole movement of self-organization. Indeed, some scientists conceive this self-organizing movement as a cognitive system.[2] Yet science tends to interpret its results about the body within the conceptual framework of experimental method, and this framework, with its criteria of objectivity and repeatability, tends to 'dismind' the body once again by reducing self-organizing systems to a conjunction of laws.[3]

This is where Hegel's speculative analysis of the logic of measurement can help. In section one, I show how Hegel's analysis of the demands intrinsic to thinking in general can elucidate the explanatory demands that configure scientific thinking and its appeal to measurement. In section two, this general parallel lets me elucidate a pattern of thinking that drives science to different strategies of measuring the body, which I trace from the work of scientists Nikolai Bernstein to Esther Thelen, until science eventually encounters a self-organizing identity that Hegel would call measureless. In section three I show in more detail how scientific thinking parallels the pattern that Hegel traces in his analysis. The approach that I take here, of rethinking the body *via* an analysis of drives internal to scientific thinking, is meant to complement experiential and phenomenological approaches to the body, by showing how scientific thinking drives itself past the

experimental criteria of objectivity and repeatability to an investigative framework that includes individuality and history. In the conclusion, I suggest that this framework demands that we think of a 'mindfulness' already at work in the self-organization of the body. Ultimately we need to move beyond all conceptual divisions of mind and body, to think of a more fundamental, unitary phenomenon like Dewey's body-mind or Merleau-Ponty's flesh; but given that our tradition still pursues this phenomenon in terms of body and mind, what is presently required is conceptual analysis of those terms, and I here focus on body.

I) Hegel's Speculative Science, Experimental Science and Measure

Hegel's *Science of Logic* provides a scientific, speculative analysis of logic, of the categorial structures and relationships that inhere in thinking anything at all. By saying that the *Logic* is scientific, I mean that it aims to be a *Wissenschaft*, a knowledge endeavour that rigorously and exhaustively secures its own principles and methods in relation to its object. To achieve this rigour, the *Logic* moves through a dialectic in which thinking examines its conception of its object. Contradictions in this conception lead to new insights about the object, categories and processes of thinking. The dialectic's results do not depend on simple empirical claims about objects or psychological/cognitive claims about the faculties of thinking, they have validity in virtue of the constraints inherent in the very conception of various categories of objects. Hegel will locate these constraints in the experienced identity of thinking and being.[4] When I say that the *Logic* is speculative I mean that its validity arises at this conceptual level, and that it develops by way of insights demanded by the identity of thinking and being.

Experimental science, hereafter referred to simply as "science," may not be concerned with Hegel's question of how we are to think anything at all, and it is not constrained by the speculative concept of the identity of thinking and being. But science is concerned with explaining things, and to do so it thinks of objects in general. Given the demands of explanation, scientific thinking and its object mutually constrain one another. As I show below, the demands of explanation thereby generate a pattern of thinking cognate to the pattern generated by the speculative identity of thinking and being that Hegel traces in the *Logic*.

Let me introduce the parallel through a brief reflection on scientific reduction. To reduce biology to chemistry is to find a domain of entities possessing greater generality than the entities of biology: chemical elements promiscuously combine to form a multiplicity of different organisms, and non-organic beings as well; but living beings combine themselves in limited ways and only produce limited species of organisms. Chemicals are more basic and pervasive entities than living beings, and it is because of this that science can aim to reduce biology to chemistry and not the other way around. If science is to continue reducing one domain to another, it will end up having to think about the most general and pervasive entity of all, the universe.

Since the universe as a whole is not an object of direct empirical study—it is just too big—science's claims about it will be constrained not merely by empirical observations but by the universe's conceptual role in explanation. Scientific thinking and its object are here specified by mutual constraints emerging from the demand of thinking of an object in general that will *explain* all else. Given this constraint, it is inconsistent to think of the universe as a static being, for then we would have to refer to some determinate

phenomenon outside of the universe that would explain why the universe starts and why it ends up one way or another. It is logically necessary to think of the universe as a spontaneous becoming that 'explains' its content insofar as the universe simply is the *becoming* of all this content. The explanatory demand that constrains science entails a pattern of thinking cognate to the one traced in the famous initial dialectic of being, nothing, and becoming in Hegel's *Logic*.

If the becoming of the universe is to explain all determinate phenomena then the universe must have an underlying, continuous unity, otherwise it would not be a unified framework of explanation, and this continuity must be articulable and quantifiable, otherwise it would not be able to explain a multiplicity of phenomena. But if the universe is to explain a multiplicity of qualitatively different phenomena, then its quantifiable continuity must be united with the qualitative determinations that it is to explain, and this continuous unity of quality and quantity is what we find in variable quality. To conceive variable quality as explanatory of a multiplicity of determinate things demands quantification through measurement, that is, through an activity that attends to the way that a quality is itself variable. So the explanatory demand inherent in scientific thinking drives it to measurement. The pattern of thinking here is cognate to the one Hegel traces when he shows that categories of quality and quantity logically develop into categories of measure.

What I have suggested so far is that the scientific task of thinking about something that would explain everything generates conceptual pressures and transitions cognate to those that are, according to Hegel, intrinsic to the speculative task of thinking anything at all. (We must not, however, conflate the two tasks of thinking.) Securing this parallel would require an exposition of Hegel's *Logic* that cannot be given here, but the parallel can be derived by attending to the issue of indifference in the *Logic* and in science.[5]

If science is driven by the demand to explain, then measurement must be conceived as an activity the very concept of which is to quantify dimensions of variable quality in order to explain the wide variety of phenomena that we see around us, rather than an activity governed by purely technical or empirical demands. If this is the task of measurement, then measurement is coherent only if what is measured matters to the things we are explaining. Hegel captures this point in the formula that "all that exists has a measure," which means that each thing has *its own* measure.[6] We therefore need to measure things in a manner appropriate to them, and we are left wondering what units and dimensions are proper to something's *own* measure.

Comment [DM1]:

II) Measuring the Body

Hegel's analysis of measurement uses chemistry as an example. I discuss the body, and argue that there is a parallel between the two patterns. My realization that there is a parallel, despite an important remark by Hegel (discussed below) which suggests that measurement fails when it comes to the body, was enabled by John Burbidge's lucid exposition, in *Real Process: How Logic and Chemistry Combine in Hegel's Philosophy of Nature*[7], of the logic of measurement in the case of chemistry. In this section I analyse the explanatory demands that drive science through a series of strategies for measuring the body. My analysis both draws out the logical pattern that Hegel traces in his speculative analysis of measurement, and illustrates the principles and point of Hegel's analysis. It thus prepares for the next section, in which I return to details of Hegel's analysis to deepen the parallel. This

two step procedure tempers the technical difficulties of Hegel's discussion of measure. To facilitate the procedure I number important steps in the pattern.

To begin, measure *qua* mattering to something's own being is what Hegel will call real measure, and I use this term to refer to it.[8] Every thing has *its* real measure locked up within it, and unlocking this unity of quality and quantity will allow science to explain the thing within a more general framework. Given its qualitative variability, a measurable being can vary relative to itself, and this gives us a logical basis for establishing a system of measure. To set up a system of measure, we can compare something to its own variations, or, better, compare it to something of the same variety, since it is contradictory to measure something by varying its measure. We can, for example, line things up against each other to measure their length. Such external comparison brings qualities of something's internal, real measure to the surface. But any directly measurable quality, just in virtue of being brought to the surface by an external standard, will indifferently apply to a multiplicity of beings: once we figure out how to make rulers, we can give the length of anything, but the length of a thing in and of itself tells us almost nothing about that thing.[9] It is not a real measure in the sense discussed above. This implies a tension, since the very point of measurement as a strategy of explanation is to have our exterior standards actually get at the interior structure that matters to the thing. We need explanations and thence measurements that *matter*. This logical tension drives the pattern that emerges below.

1) To give an example, the length of a leg surfaces in external comparisons and is thus like any other length, it is superficial and abstract. But the length of the leg is not just any length, it is really the length of a leggy, voluminous mass. Now the relation of mass to volume through the leg's length picks out its centre of gravity. This gives something closer to a real measure of the leg, since the centre of gravity matters to the leg, e.g., it constrains leg action and helps explain how legs move. But in the leg itself the centre of gravity as such is not differentiated from the continuous, living unity of mass and volume in the leg. So we render the centre of gravity discrete by locating it through ratios of volume, mass and length.

Logically, any of our attempts to get at real measure will have the form suggested above. The only way we can immediately quantify a thing's variable qualities is through superficial, external measures. But this tells us almost nothing about the thing as a unity of quality and quantity, it measures a quantity that is measurable in just about everything else—the very generality of such basic measurements prevents them from explaining the determinacy of a thing. To get at a thing's real measure, to get at a unity of quality and quantity that matters to it, we must pit two or more of its superficial measures against each other and see how they surface in a ratio.

Hegel suggests that this can lead to a sort of "derangement" in which reason mindlessly throws qualities together in an effort to get to the real measure of something. In the organic world the number of qualities and relations multiplies, and so does the possible derangement. Further, Hegel writes that "The limbs of the animal organism have a measure which, as a simple quantum, stands in a ratio to the other quanta of the limbs; the proportions of the human body are the fixed ratio of such quanta. Natural science is still far from possessing an insight into the connection between such quantities and the organic functions on which they wholly depend."[10] He thus suggests that the natural science of his time becomes quite deranged when it

tries to link the ratios that surface in the human body, which describe its shape and structure, to the body's organic function. I contend, however, that recent achievements allow science an insight into this link. More than that, Hegel's logical-speculative pattern elucidates the pressures and transitions leading to this insightful link.

The logical-speculative pattern that leads to this insight follows from two conceptual constraints: (a) that explaining the body in terms of its real measure logically entails approaching its measures in terms of ratios of external measures, as argued above; (b) that what we are trying to explain is the living body, not the dead body. The second stipulation is quite important. One reason why the organic science of Hegel's time fails to find the above link is that it lacks techniques for measuring the *living* body—it does not measure the body in motion.

Let us continue with the example of the centre of gravity of a limb. Russian physiologist Nikolai Bernstein noted in 1934 that investigators had tried to locate this centre by dissecting frozen cadavers, "following which the separate limbs were weighed and their centres of gravity determined by one of the methods of elementary mechanics." In Bernstein's ironic words, the above technique begs "the most important question of all—to what extent the relationships that hold true for cadavers are characteristic of live subjects." If we want a real measure, one that matters to living movement, it is little use to give a measure of a dead body.

2a) But how is science to overcome this problem if, as Bernstein notes, it appears to be an "impossible business to weigh a living human being, as it were piecemeal"?[11] Bernstein's solution pits the living body against itself by weighing "the [living] subject in numerously carefully determined controlled positions" on special scales, whilst photographing the body. The balancing of the body's masses against itself in a static moment can then be compared across different positions of the body, for example, lying flat, or having legs pointing upward.[12] The centre of gravity of a part of the body is thereby isolated, by seeing how shifting the part shifts the centre of gravity of a larger whole. Rather than measuring simple volume/mass ratios of an isolate part, which is possible only in the case of dead bodies, we are compounding such ratios by seeing how they relate across different parts of the body, in the series of such compound ratios generated when the living body adopts various positions. We are letting the body take the lead here—we are getting to the variable unity of quantity and quality in the body by letting it specify a series of measurements that belong to its variability. The organizing principle is no longer the way we bring external measures to the body, but the way the *living* body organizes these measures across its variations.

2b) Bernstein subsequently compares these results across different bodies, which allows him to generalize the location of the centre of gravity. Instead of saying the centre of gravity is so many centimetres down the leg, it can be specified as a percentage of the length of *any* leg. This puts a real measure of the body in terms of the body's own units, 'percent-of-leg-length,' rather than centimetres. This unit is necessary to a real measure of the leg, for it means very little to say that the centre of gravity of a leg is N centimetres down the leg, given that legs grow to very different lengths. It is notable that such tables are keyed to body types e.g., male vs. female, so the measure is really 'percent-of-leg-length-of-a-particular-kind-of-body.' Esther Thelen's work, discussed below, shows how changes in mass distribution within the leg as an infant grows explain why the infant's post-natal ability to make stepping movements vanishes around six months and

reappears later on. Measures of centre of gravity, etc., that are given in terms of particular bodies matter to the organic function of the body, and help explain it.

It seems we are getting closer to a real measure of the body by seeing how ratios of external measures, measured in *units* of a particular body, matter to the body. But the body does not distinguish mass from volume and relate them, we do, and in the body these ratios exist as immediate unities that are inseparably united with other varying qualities. Our measures impose alien dimensions on the body, and when we measure the way that volume and mass intersect in it, we are still being superficial, although savvy. The logical demand of getting at the body's real measures is not only to give these measures in the body's own *units*, but in the body's own *dimension*. Yet our initial problem remains: we can only approach the living body through externally measurable dimensions. So how can we get at the living body's own dimensions, and what would such a dimension mean?

3) The solution lies in pitting the body not against itself, but against its own other. In pitting the body against itself we abstracted it from its own environment to see how the dimensions in which *we* explain it matter to it. If we did not literally freeze the body and cut it apart, we immobilized it on a scale and moved its parts around; we allowed the body to live, but what we studied was a body frozen in time by photographs. Controlled laboratory conditions precisely limit the body's relation to otherness—we impose the apparatus and dimensions of our explanatory thinking on the living body and thus finesse it into measuring up to our own dead standards.[13] Bernstein is an innovator in getting past this problem imposed by the laboratory, since his later studies looked into the work of the *living* body. For example, he used a technique similar to cinematography to study the body hammering an object, and thus observed the body relating to *its own* other, its work and object. Instead of immobilizing the body and measuring static moments, he measured smooth variations in 'real time.' In this way he could see how the body deals with *its* world, and for reasons suggested above, such a study is necessary to reveal *dimensions of interaction* that matter to the body. Indeed, the availability of devices for recording the dynamics of living processes seems fundamental in enabling science to get past the derangement that Hegel observed in the organic science of his time.

4) Bernstein's studies let him understand that the body does have its own internal dimensions. Let me explain what this means by describing a recent (1994) series of studies of the development of walking conducted by the developmental psychologist Esther Thelen. If we measure walking within an alien dimensional system, we specify it as a series of positions of the joints and centres of gravity of the limbs, and so on. The question of how we learn to walk then becomes the question of how we learn to control our body, such that it moves through these positions. But this explains walking in terms alien and indifferent to the body and its life. Thelen's research is informed by dynamic systems theory, which has its roots in Prigogine's theory of chaotic systems, and in psychology draws on Bernstein's understanding of bodily movement and J.J. Gibson's ecological psychology. As a dynamic systems theorist, she argues that we do not control our bodies in terms of alien systems of measurement, rather walking arises within the chaotic interaction of the body and its environment, and is controlled by the ensuing self-organization of the body as dynamic system.[14]

She shows this *via* a study of how the leg moves when infants make repeated kicking

motions. Thelen graphed the angle at the knee joint against knee velocity, with all the data pairs collected over the time of an individual infant's kicking plotted on the same graph. This gives a picture of the leg's position in a space of possible external measures over time, which is called a phase space. It turns out that the trajectory of a kick graphed in phase space (that is, the pattern of relations between the paired variables over time) always follows more or less the same pattern. The body has an affinity for falling into this pattern; in the terminology of dynamic systems theory, there is an 'attractor' in the phase space, a pattern to which the possibilities of the system are 'attracted.'[15]

In terms of the leg, the upshot is that the leg itself has a certain spring-like propensity for making complex kicking motions. The infant's brain does not manipulate a representation of its limb in the alien dimensions of science in order to kick, which is what some theories would imply. When the infant is upright, this same propensity shapes the leg's movement into a step.

In terms of the logic of measure, Thelen's picture of phase space is a snapshot of a series of ratios generated by the body's relation to its own other. The simplicity and unity of the pattern that emerges in the series determines an internal dimensional system of the leg. In Thelen's terminology, the attractor is an invariant that collapses the indefinite complexity of the multi-dimensional space in which *we* plot the leg's measures—the space in which scientific thinking becomes deranged by conflicting qualities—into one simple pattern. As Turvey and Carello put it when discussing a cognate result, the body does not measure the location of its arm within an external dimensional system; rather, moving the arm "incurs a time-dependent tissue deformation pattern" that is "expressed in the intrinsic co-ordinate system defined by the muscles and tendons of the forearm."[16] *The body is intrinsically a living measure and dimension of the location of its arms and legs*, that is, *limb location as it matters to the body refers to this intrinsic co-ordinate system of the body, not to a location in an exterior dimensional system.*[17]

Scientific thinking now seems to have a leg up on the body. The invariant pattern and dimensional system revealed in the attractor are inseparable from the leg's own dense and massy structure, its own dimensions of being. In this way science links organic functions of the leg, stepping and kicking, with the leg's proportions, and makes progress past the science of Hegel's time, which, according to Hegel, could not find such a link.

5) But this result means that scientific thinking has to give up positing its own dimensions for measuring the body, and will have to give up measurement in the usual sense. Suppose we construe the attractor as collapsing the deranged multiplicity of abstract dimensions and ratios of measures into one simple pattern. This conceives the internal dimension in terms of our own external measures, as if measures in this dimension would smoothly vary according to some mathematical product of the external dimensions that it collapses. But dynamic systems theory argues against this conception. Attractors are discovered in phase spaces, and show how science's external measures intersect in the body, as the body shapes itself against itself and its own other over time. Attractors thus emerge out of the body's self-shaping, chaotic interaction with the environment. The self-shaping body in its environment as it were enacts attractors, congealing them out of the smooth continuum of science's external measures, so scientific thinking can neither specify the attractor apart from its congealing in the existence of the body, nor

conceive the attractor as reductively correlated with magnitudes of those external measures or their products.

This is shown by the fact that a change that appears to be smooth when specified in terms of external measures can lead to an abrupt qualitative change in phase space, to the enactment of a new attractor. If you put me on a slow moving treadmill and gradually turn up the speed, at certain points I will shift from walking to jogging to running, and the shifts will be abrupt. The attractors that describe the pendular counter-rhythms of my legs suddenly shift their configuration, since walking, jogging and running demand quite different rhythms, as we all know. Attractors, as determining internal dimensions of the body, cannot be correlated with a calculative product of the dimensions that make up their phase space. They have their own leaps and bounds that are not predictable by any combination of ratios of our external measures, since the interrelation of measures is intrinsic and inseparable from the body's own being and becoming in its environment. Little is explained by making mensural comparisons between attractors, for example, by saying that walking happens at speed V_w and jogging at speed V_j; this may be true, but the quantity $\Delta V = V_w - V_j$ does not explain much, since what is significant about attractors is the set of dynamic behaviours that they identify, and the values V_w and V_j cannot on their own explain those dynamic identities.

The living body *qua* embodying such attractors is what Hegel calls measureless: we cannot bring its transitions into an abstract system of measure, the body is *absolutely indifferent* to our system of measurement.

III) The Parallel Between Measuring Bodies and Hegel's Analysis of Chemical Measurement

I contend that what drives the pattern of explanatory thinking and strategies of measurement traced above is cognate to what logically drives the movement from measure to the measureless in the *Science of Logic*. That is, remarkably, the demands that pattern the conceptual history of giving measures that get better and better at capturing the real behaviour of the body, from Bernstein through Thelen, are cognate to the demands that pattern the ever more complex forms of measurement laid out in Hegel's speculative analysis, and the patterns are also cognate. To show this I return to the numbered steps in the previous section, discussing and identifying them in terms of transitions in Hegel's study of real measure in the *Logic*. I do this *via* Burbidge's analysis in *Real Process* of what Hegel has to say about the measurement of chemicals.

1) From specifying measure to ratios of measures: The problem that haunts the first step is the problem of how we are to specify measurements of things, given that basic measures and their standards are external to what is measured. E.g., to specify that a sample of pure copper has so much mass or volume is to say very little about it chemically, because a sample of hydrogen could have the same mass or volume. But to say that the sample has a certain specific gravity, that it is so many times denser or less dense than a reference substance, is to say a lot about it, because density matters to the chemical itself. This chemical measurement strategy, of turning to the specific gravity, has its cognate in the strategy of measuring the centre of gravity of a leg: both measures combine external measures. In the *Logic* this is the step from specifying measure to real measure as a ratio

Comment [DM2]: Let me return to Thelen to show how science has to give this up too. Thelen shows that when the infant is upright, the invariant pattern that produces a kick is shaped by gravity so as to produce a step-like motion. She argues that walking is a kind of interplay between the infant and the world, in which falling forward pulls the leg back, and then muscle firing helps the leg spring forward in a stepping motion. Above we talked about one leg in abstraction from the body, so a question that follows is how does a pattern of bipedal stepping develop, in which one step alternates with an other? In other words, how does the real measure of the leg belong to the real measure of the bipedal body? Thelen noticed that when an infant is placed over a treadmill and the treadmill drags a leg back, the infant can make a stepping motion, even if the same infant cannot do this when she is held above a surface. So Thelen set out to study infants on treadmills to see how bipedal, alternating stepping might arise. Amongst many other results, she found that alternating stepping was more stable at faster, rather than slower, treadmill speeds, and alternation as a pattern stabilised after the infants was to four to five months old. Thelen's analysis posits alternating stepping as an attractor of the behaviour of the infant as a whole, and what these results mean is that this attractor undergoes a 'phase change' when certain external variables such as treadmill speed or infant age vary.

of measures. (Cf. *Real Process* 28-33 and *WdL* 388-392/ 348-349.)

2a) From a ratio of measures, to a series of measure relations: Measuring the leg's centre of gravity through simple ratios of mass, volume and length would be fine if we wanted a real measure of dead, detached limbs, but as Bernstein points out we want a measure that matters to the leg as part of the living body. The problem here is cognate to the chemical problem that a simple measure of a chemical's specific gravity underspecifies its chemical identity. Specific gravity varies with temperature and pressure, different compounds might have the same specific gravity, and in any case chemicals are not inert. A real measure would capture the identity of the chemical as live and reactive. The solution to the chemical problem is: (A) to compare the specific gravity of a chemical in one condition with that of the same chemical in other conditions; and (B) to see how the chemical's specific gravity alters when it reacts with other chemicals. This gives a profile of the chemical as a reactive agent. Even though two chemicals may share certain static properties, e.g., specific gravity, they could not share all properties across a 'reaction profile,' else they would be the same chemical. Generating this 'reaction profile' logically entails comparing (i) the series of measures obtained when the target chemical reacts with a slate of other chemicals with (ii) similar series for the slate of other chemicals. The upshot is a measure of the chemical within a 'reaction space.' More bluntly, in the end, identification of chemicals through measurement is incoherent apart from some theoretical framework of measurement like the periodic table. The general logic that drives this procedure of measuring from simple ratio to a series of ratios is quite complex and extends into steps 2b and 3 below. It is discussed in *WdL* 392-396/ 351-354; *Real Process* (pp. 34-40) does an admirable job of laying out the complexity of the compounding and series involved.

When Bernstein lets the body generate a series of relations between centres of gravity across different positions of the living body on his special scales, he is doing something cognate to step (A) above, but it already elides with step (B) in the sense that the body is playing the role of an entire chemical system. Putting the body into different positions and seeing how the centres of gravity combine in new ways is akin to combining live chemicals in different ways.

2b) Bernstein's strategy of comparing results across different bodies extends step (B). It is cognate to giving chemical measurements in terms of a variability found within the system of chemicals, rather than proportions of external measures. We are measuring bodies in terms of variability that matters to bodies, rather than the variability of external measurement systems.

3) Toward elective affinity: The above strategy still has the problem of measuring a thing in terms of an external system that is conceived merely as a dimension in which to measure the thing. But if the thing can be measured in that system, it is because that system matters to the thing itself. To get a real measure, we need to see how that system matters to the thing itself. We were already getting a sense of this when we saw how a chemical reacted with other chemicals in its environment, which shows how the chemical system matters both to the alterability of the chemical and to its identity through alteration. Bernstein's and Thelen's strategy of studying the movement of the living body is cognate: rather than seeing how various positions of the living body generate a static system for measuring the body, studying movement shows how a moving system of body positions matters to

the living body itself in relation to its environment.

5) From the series of measure relations to elective affinity: If the thing's interaction with its environment can matter to the thing, it is because the thing interacts with its environment in quite specific ways. We notice this when, e.g., we shift our attention from the values that we record when looking at varying densities in the 'reaction profile' of a chemical to the *pattern* of chemical reactivity exhibited by this profile. This pattern would in Hegel's terms specify the 'elective affinity' of a chemical, giving a complex picture of how the chemical electively combines with other elements. The pattern identifies how the chemical relates to its 'reaction space,' and how that 'space' relates to the chemical. The strategy of plotting bodily measures as co-ordinates in a phase space similarly draws a pattern of reactivity to our attention, the attractor, which gives a complex picture of an 'elective' dynamic within the body, a chaotic, self-similar tendency of the body to be in certain states in its interaction with its environment. (See *Real Process* 40-43 and *WdL* 396-410/ 354-366 for more on the logical transition between the series of measured relations and elective affinities.)

6) From elective affinity to the nodal line and the measureless: Once we are looking into elective affinities or attractors, the significance of our measures will no longer be that of a scale of quantities correlated with a scale of qualities specified by some mathematical function. With the elective affinity or the attractor we have an insight into some 'knot' of qualitative relations that happen to congeal correlative to a fixed point on a scale of quantities, but the mere correlation between quality and quantity does not explain the phenomenon. No quantitative explanation will explain the correlation between temperature and the freezing point and boiling point of water, rather Hegel calls these 'knots' or 'nodal points' along the smooth spectrum of temperature. We have to look into what essentially belongs to water, especially at these 'nodal points' to get some insight to the correlation. And once we are interested in that, what really matters is something measureless. (On these transitions, see *Real Process* 44-51, *WdL* 410-419/ 366-373.)

Conclusion: Rethinking the Body

The above shows that scientific thinking *qua* constrained by the demand of explaining things is driven through a conceptual pattern cognate to the one that Hegel derives in his *Science of Logic*. It would be going too far to say that the pattern of Hegel's *Logic* specifies the rich mix of empirical and conceptual problems and solutions that shape the history of science, or that his conception of 'nodal points,' the measureless, etc., anticipates the concepts of dynamic systems theory. I make a more qualified claim. The mutual constraint of thinking and its object govern the procedure of both Hegel's *Logic* and scientific thinking; the former constraint emerges from the speculative identity of thinking and being, the latter from the demands of explanation. My claim is simply that on a large scale the demands of scientific explanation impose constraints cognate to those of Hegel's speculative philosophy, and that the pattern of thinking that follows, namely, the turn from measure to the measureless, is cognate to the one Hegel derives.

Recent results in science show that in fact science is making such a turn from measure to the measureless. To add an example to the ones given above, dynamic systems theorists Carello and Turvey show that we feel the length of objects like canes by feeling how we can use them, and those uses "are not simply a function of geometric dimensions such as length and width but, in

a very real sense, how those objects can be moved (e.g., whether or not they are 'unwieldy')."[18] Carello and Turvey turn from external dimensions such as length and width, to 'dimensions' such as 'wieldiness' that could only matter to and within living body.

But in light of my claim, I want to urge a bit more. We should interpret these results not merely as empirical data, but as indicating that scientific explanation inherently demands a turn away from measurement, a turn cognate to the one that Hegel traces in his *Logic*. The very demand of giving an explanation of everything in general has turned into the demand of comprehending essential identities that cannot be reduced to an "everything in general," because the beings that we want to explain are self-organizing, they exist by forging themselves within the universe as a whole *qua* basis of explanation. We need to comprehend how such beings *explain themselves* through what essentially matters to their existence as self-organizing—we explain them by comprehending how they organize themselves, not by reducing them to external dimensions.

This means that the explanation of self-organizing things is, so to speak, packed into their dynamic of self-organization. So *we must explain such things through their own history, rather than through some neutral dimension prior to their own history*. In her recent book, *Dynamics in Action*, Alicia Juarrero insists that dynamic systems be understood as historical and containing their own history, e.g., she writes, citing Prigogine, that "complex systems do not forget their initial conditions: they 'carry their history on their backs.' Their origin constrains their trajectory."[19] To put it another way, we have, in effect, had to wait for self-organizing things to come into being so that we may study them. We therefore cannot explain them in terms of abstract dimensions that we isolate in the present. We must study what we have waited for, and this includes their own time of becoming, in which they create the dimensions in which we study them, a strangely Bergsonian principle in this context.

In the case of human beings, this becoming is individual, and as Thelen and Smith argue, "*the individual and his or her behavioural changes over time are the fundamental unit of study*."[20] We will have to study social, cultural and individual history, a point taken to heart by Thelen, Smith and Fogel, amongst others who observe that the dynamics of individual human bodies, even of such seemingly mindless and mechanical actions such as reaching, depend on development in a social milieu.[21]

This is where the challenge to 'disminding' the body arises. A body whose terms of explanation are packed into its own history is 'mindful' at least so far as its own process 'authorizes' the terms we bring to its explanation. This complex conceptual point shows itself empirically if we note, as do Fogel, Thelen and Smith, that the essential identity of the self-organizing body arises through its mutual implication in other bodies. This mutual implication is fundamentally social, communicative and expressive—and sociality, communication and expression are mindful activity. The body that we tried to explain through an appeal to the underlying continuity of the universe and its measurable dimensions of matter instead has its identity only within an historical sphere of social identities, and this sphere is *mindful*. The reductive move, of explaining all the terms of this sphere *via* a 'disminded' explanatory substratum, is blocked by the very demands of explanation, because the mindfulness of the social-historical sphere becomes integral with the very body being explained.

Dynamic systems theory *discovers* that the reductive move is empirically problematic. What I have tried to urge by drawing a parallel between the pattern of Hegel's *Logic* and the pattern of scientific thinking is that in the end the reductive move is *conceptually* problematic. The block to reduction, I want to suggest, is conceptually inherent in the very matter of explanation, and calls for a reconception of the framework of explanation. Body and mind cannot be isolated as two terms that can be reduced to one, from the start our fundamental conceptual unit must be body-mind as self-organizing individual integrated with its history. We cannot aim to reduce mind to a neural substratum in the biological body because we comprehend that the very thing that drives our question, a being that organizes itself as a mindful-body to be explained, exists only if it grows up as an individual in a society that is already mindful and that enables the scientific community in which we study one another's minds. And if we wish to appeal to some prior sphere to explain how society and individuals came about such that they enable mindful self-organization, if, in other words, we wish to give an account of the genesis of this sphere, then here too we will have to see that the crucial transitions are self-organizing and mindful.

Does this mean an end to scientific thinking about the body? Do we have to start explaining body and mind by appealing to some mysterious mental substance? I do not think so. Rather, we have to rethink what counts as an explanation and what counts as nature. Reductive explanation seeks to explain things in terms of a nature that is logically independent of what is being explained. But if the things that we wish to explain, like the body, forge themselves within nature, then nature is not independent of what we wish to explain. We can give explanations of mind and body as natural phenomena, *but the nature in question will no longer be the same*, it will be a nature in which individuality and history are inherent. Learning to think of nature in this way, and of body-mind in terms of this nature, will be an extremely difficult conceptual task, and this paper makes only the slightest contribution to this task, at the broadest conceptual scale. Perhaps an extension of Hegel's speculative *Science of Logic* in the direction I have taken so far will help with this task, and I suspect that a study of the "Doctrine of the Concept" in that book will be requisite to such an extension. In any case—and here I echo Renaud Barbaras's conclusion and sentiment in "The Movement of the Living as the Originary Foundation of Perceptual Intentionality"[22]—rethinking the body so as to give an account of the unity of mind and body will entail rethinking nature.[23]

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[1] Maurice Merleau-Ponty, *Phenomenology of Perception* (New Jersey: The Humanities Press, 1962), esp. "The Tacit Cogito." John Dewey, *Experience and Nature* (New York: W.W. Norton Norton & Company, 1929), esp. "Nature, Life and Body-Mind." In *The Primacy of Movement* (Amsterdam: John Benjamins, 1999), Maxine Sheets-Johnstone gives a sustained argument for the centrality of movement in thinking.

[2] Cf. e.g.,Francisco J. Varela, "Organism: A Meshwork of Selfless Selves," in *Organism and the Origins of Self*, ed. Alfred I. Tauber, 129, 79-107 (Dordrecht, Netherlands: Kluwer, 1991).

[3] See, e.g., David Morris, "The Fold and the Body Schema in Merleau-Ponty and Dynamic Systems Theory," *Chiasmi* 1 (1999): 275-286.

[4] This identity is secured in Hegel's science of experience, given in the *Phenomenology*

of Spirit. On this identity and its role in the *Logic*, the following are helpful: Gadamer's "The Idea of Hegel's Logic," in *Hegel's Dialectic: Five Hermeneutical Studies*, trans. P. Christopher Smith (Yale: Yale University Press, 1976); Jean Hyppolite, *Logic and Existence*, trans. Leonard Lawlor and Amit Sen (Albany: State University of New York Press, 1997); H.S. Harris, "Hail and Farewell to Hegel: The *Phenomenology* and the *Logic*," *The Owl of Minerva* 25 (1994): 163-171; Joseph C. Flay, "Hegel's Metaphysics" and Stephen Houlgate's "A Reply to Joseph C. Flay's "Hegel's Metaphysics" in *The Owl of Minerva* 24 (1993): 145-152, 153-161.

[5] Science's demand for general explanation can be construed as a demand for an explanatory substratum that is indifferent to what it explains. But so far as the substratum explains, it is not entirely indifferent to what it explains. Throughout the doctrine of being, Hegel characterizes various categories as complex forms of indifference, and we can read his dialectic as showing the contradictions of forms of indifference; the categorical shifts that ensue are cognate to the shifts in scientific thinking that I discuss in this paper.

[6] *Wissenschaft der Logik: Die Lehre vom Sein (1832)* (n.d. *Gesammelte Werke*, Band 21, hrsg. v. Hans-Jürgen Gawoll, Hamburg: Felix Meiner Verlag, 1990), 317; Hegel, *Science of Logic*, trans. A.V. Miller (Atlantic Highlands, NJ: Humanities Press International, 1969), 373. It belongs to the very structure of a measurable thing that it "is not indifferent to this magnitude," thus "Everything that exists has a magnitude and this magnitude belongs to the nature of the something itself." All subsequent references will be of the form: *WdL* page in Meiner/ page in Miller's translation.

[7] Toronto: University of Toronto Press, 1996, hereafter cited as *Real Process*. Burbidge also defends the sort of discussion that I engage in here, viz. one that draws Hegel's *Logic* together with science.

[8] *WdL* 389/348.

[9] Cf. Hegel's point that a unit of measurement can be "an intrinsically determinate unit, like a foot and suchlike measures; but in so far as it is also used as a standard for other things it is in regard to them only an external measure, not their original measure." (*WdL* 371-372/334) This problem resolves in real measure as internally relating external measures. (*WdL* 375-388/336-347)

[10] *WdL* 369/ 331-2. Also see Hegel's comments about proportions of animal bodies in the *Encyclopaedia Logic*, *Enz.* §107, *Zusatz*. *Real Process* makes this process of derangement very clear in the case of the inorganic; see in particular chapters 5 and 9.

[11] N. Bernstein, *The Co-ordination and Regulation of Movements* (translated, foreword by A.R. Luria, Oxford: Pergammon Press, 1967), pages 9-10.

[12] I reconstruct this from Bernstein pages 10-11 and Figure 12, and from subsequent authors who draw on Bernstein and take up similar issues. Bernstein does not spell out his process, saying it is too complex, and I cannot locate a translation (from the Russian) in which he does.

[13] Getting past this problem is the point of J.J. Gibson's emphasis on the ecological in psychology—we are to study the organism in its ecology, not the organism on its own. Also see Merleau-Ponty's criticism of laboratory studies of living beings

throughout *La structure du comportement* (Paris: Quadrige/Presses Universitaires de France, 1942). His main point is that the organism studied in the controlled conditions of the laboratory is not the same as the organism in its own environment. (Cf. pg. 164) On these issues also see Goldstein's *The Organism* (New York: Zone Books, 1995), which is influential in Merleau-Ponty's thinking.

[14] See Esther Thelen and L.B. Smith, *A Dynamic Systems Approach to the Development of Cognition and Action* (Cambridge, MA: MIT Press/Bradford Books, 1994), chapters 1-3.

[15] Thelen and Smith 1994, chapter 4, especially pages 78-83.

[16] M.C. Turvey and C. Carello, "Dynamic Touch," in *Perception of Space and Motion*, ed. William Epstein and Sheena Rogers (San Diego: Academic Press, 1995), 401-490, page 478.

[17] This claim is extrapolated from M.T. Turvey, Kevin Shockley, Claudia Carello, "Affordance, Proper Function, and the Physical Basis of Perceived Heaviness," *Cognition* 74 (1999), B17-B26, which argues that felt heaviness does not refer to the weight of an object but to measures S and V which characterize the inertia tensor of the object with reference the body that wields the object. The referent of heaviness is to be found within a dimension that cannot be specified exterior to the body.

[18] Claudia Carello and Michael T. Turvey, "Rotational Invariants and Dynamic Touch," in *Touch, Representation and Blindness*, ed. Morton A. Heller (Oxford: Oxford University Press, 2000).

[19] *Dynamics in Action: Intentional Behaviour as a Complex System* (Cambridge, MA: The MIT Press, 1999), 139. The consequence, according to Juarrero, is that scientific explanation must turn into 'hermeneutics': "Non-linear, essentially historical phenomena cannot be explained deductively-nomologically because they are not already there waiting to be rolled out and thereby explained." (220); "I propose that explaining complex systems, including human beings and their actions, must therefore proceed hermeneutically, not deductively." (222); this is because "The interlevel tacking of the hermeneutic "circle" [between part and whole] reproduces the self-organization of complex dynamical processes." (223) It is difficult to determine, though, whether Juarrero's actual sketches of such hermeneutic explanation actually make use of the concepts of dynamic systems theory in a way that is more than metaphorical, and *vice versa*.

[20] Thelen and Smith, 1994, page 97, their emphasis.

[21] See the works of Thelen and Smith cited above and e.g., A. Fogel, *Developing through Relationships: Origins of Communication, Self, and Culture* (New York: Harvester Press, 1993) and other works by Fogel.

[22] In *Naturalizing Phenomenology: Issues in Contemporary Phenomenology and Cognitive Science*, eds. Jean Petitot, Francisco J. Varela, Bernard Pachoud and Jean-Michel Roy (Standford: Stanford University Press, 1999), 525-538.

[23] This article originated in a paper presented at Trent University. I would like to acknowledge the enthusiastic response, remarks, and encouragement of John Burbidge and other members of the Trent University Department of Philosophy on that occasion. Emilia Angelova's advice and

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