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Unity without myths

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We seem to suffer from a case of cognitive dissonance. On the one hand, we seem to have almost unanimously rejected as hopeless or incoherent the aim of a unified science. On the other, we passionately debate about the prospects of research programs which, if successful, would considerably enhance the prospects of unification: from particle physics to cognitive neuroscience, from evolutionary theory to logical modeling or dynamic systems, a common motivation seems to be the quest for unity[1]. The purpose of this paper is to relieve the dissonance. I will defend a moderate form of unity, one which is compatible with the diversity and open-endedness of science, for which I can think of no better name than federalism, as it combines plurality and the construction of a common epistemic area. This view is not original: Otto Neurath himself espoused it, albeit in a context which is in certain respects quite unlike ours[2].

1. Varieties of unitarian doctrines

Let us locate the notion of unity of science in logical space. As a matter of terminology, I will use 'unitarian' and 'unitarianism' to refer to the doctrine, principle or thesis of the unity of science (rather than the better-formed 'monism' and its cognates, which need to be qualified, confusingly, as 'methodological' to distinguish epistemic unity of knowledge from ontological unity of nature).

First, we should distinguish reductive unity from organic unity. A strong form of physicalism implies reductive unity (it is in fact the only active metaphysical program in mainstream philosophy of science which does, so that in practice though not in principle the two are often taken to be equivalent). Organic unity is weaker: it maintains the autonomy of a variety of sciences (or disciplines), but insists on an intelligible articulation between them. A living body has distinguishable parts which are held together by joints which are themselves body parts and are as open to full investigation than the parts themselves; and so, for the organic unitarian, the corpus of science is, or will eventually appear as an organic whole composed of parts held together by theoretically accountable bonds. The sophisticated physicalist might argue that in the last analysis, organic and reductive unity are, or end up being the same. But not everybody will be convinced. Some French philosophers of science of the recent past, for example, have made much of the grammatical plural of "the sciences" (in French, *les* sciences), with the intent to reject any form of unity which would imply the elimination in principle and in the long run of the plurality of sciences; so they would of course reject reductive unity, while accepting organic unity. In fact, they may not have seen any coherent possibility of rejecting the latter. Perhaps this remains the case for some philosophers today: to them, the issue is between physicalism (or reductionism) *vs* what I call organic unity, which to them is the default, 'antireductionist'

[1] For an overview, see Andler et al. 2002.
[2] Among the early fruits of the Neurathian revival, see Uebel 1991, Cartwright et al. 1996, Ouelbani 1998.

position. While to me, and many others in our post-positivist age, the main contrast is between unity, whether reductive or organic, on the one hand, and disunity, a view which is assumed to go clearly beyond the mere admission of the plurality of sciences.

So we already have, at this early stage, a partial resolution of the initial dissonance. The impression that hardly anyone today defends unity is misleading: many of these alleged anti-unitarians may turn out to be organic nonreductive unitarians and thus feel comfortable about unification research programs. What does remain is, first, a sharp disagreement between the group formed by both kinds of unitarians and the radical, 'anarchistic' anti-unitarians, and second, for the latter group, the problem of finding value or sense in the pursuit of unification programs.

But there is a second dimension to the issue. Are we seeking a correct description of science as it is, or are we assigning norms to the scientific enterprise, saying what it should aim for, or assessing how distant or close it is in fact from what it should be in principle? The difficulty here is that there is no unique correct description of anything as complex as 'science as it is', so that the description we seek is itself heavily dependent on norms. The description we seek should (or so it is often assumed) show the 'deep structure' of science (whether logical, more broadly conceptual, or historical), rather than consist in an endless litany of observations, and the search for such a deep structure is perforce going to engage some of our deep theoretical commitments, amongst which those regarding unity. The unitarian will tend to seek a unitarian description, which might require quite a bit of theoretical work carried out at the meta level, though actually in some cases it may be indistinguishable from first-order scientific work. The anti-unitarian will tend to favor, in the name of faithfulness or 'realism', features which raise apparently insurmountable obstacles for a unitarian account; his is a 'lazy' strategy, requiring as it does no feat of scientific or philosophical imagination.

It thus appears that mocking an earlier generation of philosophers for offering a 'Legend' as an account of science, rather than aiming for the 'real thing' is slightly disingenuous[3]. On the other hand, arguments can be sought either in a critical examination of the idealizations which were necessary to the construction of the view under scrutiny, or in the transformations which science has undergone in the last three or four decades: perhaps a theoretical account of science which was plausible, all things considered, at a previous stage can no longer be taken seriously. But these higher-level assessments are themselves entirely open to discussion. The upshot is that there is no such thing as descriptive philosophy of science as opposed to normative philosophy of science: there are only better and worse ways of going the bootstrapping route, from our budding theories of science to science itself, which is never quite itself but always on the go.

Lastly, there is the question of the structure of nature. Is the unity of science a corollary of the unity of nature? Conversely, does the disorder of nature imply or explain the disunity of science? Poincaré thought that the unity of nature could not be regarded as a serious question, "for if the various parts of the universe were not like the organs of one body, they would not act upon one another, they would ignore each other, and in particular we would only know one of them".[4] (Poincaré would thus qualify as an 'ontological organic unitarian'). Symmetrically, John Dupré argues that the 'disorder of things' provides the 'metaphysical foundations of the disunity of science'[5]. Certainly the two claims, ontological and epistemic, sit well together, as do their opposites. But in fact the two issues are orthogonal: nature could be one and our science divided as well as united; and nature could be divided yet our science be united as well as divided. In both cases the possibility arises because we may be epistemically limited: nature could be one and we could be incapable of finding out; or nature could be divided yet our science limited to just one region of it and thus possibly united.

At any rate, as Poincaré points out, unity is not a given: it is conquered. Unification is achieved via two kinds of processes (a third will be added later). The first is the discovery of a common principle, a structuring hypothesis which reveals the essential kinship between two orders of nature initially conceived as separate. The best-known examples are provided

[3] I am not suggesting for a moment that this is what Kitcher is doing in his 1993 book. But it is a trend in some post-positivist literature.
[4] Poincaré 1902, chap. IX.
[5] Dupré 1993.

by the developments of physics, chemistry and biology in the 19th century (Faraday then Maxwell incorporating electricity, magnetism and optics into a single realm; Berthelot doing the same for organic and mineral chemistry; cellular biology connecting zoology and botany, etc.). The second unifying process is reduction: an area is reduced to another after the model provided by Boltzmann's statistical thermodynamics, bringing heat under the theoretical control of mechanics. Reduction is in principle absolute: nothing remains of the initial ontological autonomy of the reduced realm, although practical considerations will often justify holding on to its vocabulary and to some of its methods: who would want to resort to Schrödinger's equations to write an oxidation-reduction reaction, or apply the Maxwell-Boltzmann distribution law to compute the maximal efficiency of a steam engine, when well-tested macro-level empirical laws provide the answers in minutes? Besides these two constructive forms of unification, there is the case of outright elimination, when an entity is ruled out of the ontology, leaving no traces in further developments of science: Galenic humors, natural places and imponderable fluids have simply vanished (but then it can be argued that they were mere accidents along science's journey towards truth).

Unitarian views are traditionally contrasted with regionalism, which contends that there is a natural division of mutually autonomous disciplines corresponding to natural divisions of nature. As we saw, regionalism can be no other than organic unitarianism viewed, so to speak, from the angle of the 'organs' rather than the 'organism'. There is a stronger form of regionalism which denies the existence of (non-trivial) connections between the sciences, at least at a mature stage of development. The main example is bifurcationism to which we now turn.

When Neurath introduced unity of science as a thesis and as a defining concept of the Vienna Circle, his target was the bifurcation principle defended by Droysen, Dilthey, Jaspers, Weber and others, making the *de facto* separation between the human sciences and the physical or natural sciences a *de jure* unbridgeable gap. Unity was to be defended as a matter of principle, and hardly concerned the natural sciences as a disorderly collection: the aim was to put an end to an exorbitant right, used and misused by the *Geisteswissenschaften,* to conduct their business as they please, disowning in advance any critical examination from other sectors of science among the *Naturwissenschaften*. The bifurcation thesis is of course still widely held[6]. Perhaps surprisingly, it tends to support a restricted principle of unity, one restricted, on the one hand, to the natural sciences, on the other, to the human sciences. Indeed, it presupposes such a principle: for only if the two groups are in some sense homogeneous does the issue of their essential difference take on any real importance.

Here we can identify, and thus suppress, another source of the cognitive dissonance we aim to dissolve. For philosophers of science who have in the last two decades inflicted damaging criticism to the unitarian conception, the problem concerns disciplines which were until recently thought to raise *no* obstacle for unification. Their contribution to the anti-unity near-consensus is only indirectly related to the most ambitious unifying program underway, *viz.* the naturalization of the human sciences by cognitive science and evolutionary biology. That program *is* directly relevant to the initial concerns of unitarians. Among its defenders and practitioners, the more sophisticated are not alarmed by the ongoing anti-unity arguments, in fact they can welcome them. As was just suggested, a loosening of the ties between the natural sciences delivers slack for a possible tightening of the bonds between *some* human and *some* natural disciplines or sub-disciplines. Nonetheless, they often continue to lean on orthodox unitarian views when it comes to justifying their project in general terms: they claim to merely be carrying out, so to speak, historical necessity, or obeying the prescriptions of a sound conception of science. Thus Neurath's natural allies today do not all belong to any one camp: as we shall see, he has foes as well as friends in both. Some of those who are trying to substantiate the anti-bifurcation thesis which is, as we just recalled, at the heart of Neurath's and his colleagues' concern, also defend a rigid unitarianism which he rejects. By the same token, contemporary anti-unitarians are actually posthumously providing Neurath with arguments in favor of his non-standard version of unitarianism.

[6] Note that there are in fact many distinct ways of construing bifurcation, some of which are in fact quite compatible with the sort of moderate unitarianism which is defended in the present paper. But I concentrate here on an strongly separatist version of bifurcation which is not compatible.

Contemporary naturalists defend yet another position, which partakes of both unitarianism and regionalism. They rely on a different sort of unification, compatible with a certain form of anti-unitarianism. This is a achieved by a third kind of process, which combines ontological monism with epistemic pluralism by introducing filters or screens between realms of nature (levels of organization, levels of aggregation...: the issue of what it is that filters both unite and separate is thorny and one which I will not discuss here). A filter is in place whenever an entity (object, state, process) can be fully characterized, at the level where it is initially individuated (conventionally called the 'upper' level), by the role it plays in relation to other entities on that same level, without recourse to its 'nature' nor any property it might possess on the other level (the 'lower' level). Thus the theory of levers and pulleys is insulated from other areas of physics or chemistry by the fact that levers and pulleys are entities which are exhaustively characterized by the role they play in mechanical systems. The stuff they are made of, for example, plays no role at all in the theory (under appropriate idealization). A filter thus appears as a kind of antidote to reduction: whether reduction is possible or not (the issue is emergence, another topic which I will not discuss) becomes irrelevant. A proper filter, like a proper reduction, is perfect: it lets nothing from the 'lower' level contaminate the 'upper' level, save perhaps some fairly uninteresting constraints of a broad quantitative character. A theory can thus be developed for the higher level, a theory of roles or functions, with no significant contribution from lower-level facts or generalizations. Functionalism, concerning two realms of nature, is the thesis according to which a filter can be inserted between them. In its present form, functionalism is the center piece of mainstream philosophy of mind: the 'upper' level is the realm of mental, or psychological, or again informational entities, the 'lower' level that of physical (specifically, biological, or electronic) entities. But functionalism is a familiar strategy in many other fields, as can be seen by a cursory inspection of biology, economics, sociology, demography, geology, etc. In fact, it is available in principle to any discipline except the most basic one, fundamental physics. Its net effect, for the issue of bifurcation, is to make it no more interesting than the relation of say geology to basic physics: all 'special sciences', in Fodor's terminology[7], stand with respect to (fundamental) physics in the same kind of relation. Ontology is irrelevant, and one can freely choose one's camp; what matters is that explanatory dualism is seen to be no less respectable for psychology than it is for geology. Fodor's is thus a hybrid form of anti-unitarianism: disunity of science is claimed as a 'working hypothesis' compatible with physicalism. Functionalism in philosophy of mind is the target of increasingly severe criticism, and may need to be reformulated in order to preserve its intuitive core (after all, there *is* a science of levers and pulleys, so there must be something right about the very idea of functionalism). But I will leave this issue on the side, as I want to focus on what appears to me to be more central concerns, and which will also bring us closer to Neurath's opposition to unitarianism.

First however we need to ask, in the light of the preceding discussion, whether unitarians have enough common ground to make an assault on unitarianism worth the effort. I think there is: unitarians share a common ground, which is a stance they hold above and beyond any specific set of theses, and this stance involves one particular assumption which remains usually unstated yet plays a key role. The generic unitarian I have in mind assents to a significant proportion of the following complex thesis:

> *Nature being one, and science, whose purpose is to provide objective knowledge of nature, having a near perfect record of success, the horizon common to all ongoing research programs in the various disciplines is a unified and complete body of knowledge about nature. The divisions which exist today are of no theoretical import, being due to mere historical factors, some involving methodologies or instruments, many having to do with the dynamics of academic institutions. These divisions are bound to disappear, leaving at most intelligible articulations between natural domains. Their final elimination will mark the end of a long series of abolitions of borders, achieved by unifying enterprises whose success are among the highest accomplishments of science.*

The crucial assumption is that science is moving towards completeness: scientific knowledge

[7] Fodor 1974.

is admittedly incomplete, but it aims for completeness in the limit. This goal is not only reasonable, from the unitarian standpoint: it is constitutive of the unitarian view.

2. What stands in the way of unity

I will now argue that all forms of unitarianism are based on a misleading picture of science. The same can be said in fact also about classical regionalism, so that my opponents include reductive and organic unitarians, as well as classical regionalists and functionalists, while my allies include Neurath, and I suspect several leading contemporary philosophers who I will not call on in this paper for fear of making it too long.

The Myth of Purity

The first problem with all of these doctrines is that they rest on an assumption of purity, which comprises two complementary parts.

On the one hand, it is assumed that a mature science only employs representations which are purified of any intuitive content, whether originating in commonsense, subjective perception, or ordinary language. These resources play only at the boundaries of the discipline, where they allow scientists to reach an intersubjective consensus on the validity, justification, degree of empirical support, of the theories which they are considering. This requirement may be regarded as a form of epistemic purity.

On the other hand, every real, existing entity (again: thing, state, process...) is assumed to belong to exactly one natural kind. Natural kinds are the domains of natural laws, and the trajectory of any entity is entirely determined (be it probabilistically) by the laws relative to the kind to which the entity belongs (of course, in combination with laws pertaining to other entities involved and initial conditions). This may be regarded as a form of ontological purity.

These two assumptions, which have been defended and attacked independently, jointly imply that for every realm of nature, there exists an essentially unique formal language which affords reference to the elements of the local ontology, expression of its fundamental laws, and formal inferences necessary for explanation and prediction. Uniqueness results from the requirement of ontological purity, and formality from epistemic purity.

Both assumptions have been challenged. In chronological order, Neurath first emphasized that science can never be rid of what he called *Ballungen,* translated as 'clusters', which are hybrid concepts or terms with both a theoretical or scientific and a lay or intuitive component. These cluster concepts play in role in the theory in which they occur, and are scientific to that extent; but their reference is partly determined by commonsense and social or intersubjective practices which remain external to the theory. To take an example in contemporary science, the concepts of cognitive psychology, as Fodor notices, are intentional, or folk-theoretic, through and through. Yet inside the theory, they are deployed as natural-scientific concepts. In other words, they are typical *Ballungen* which both play a role in the theory and refer to phenomena which can only be identified with the help of our commonsense intentional psychology. This *matters:* as Fodor points out, as long as this will be the case, cognitive psychology will not deserve the title of natural science of the mind; and he bemoans the fact that the prospects of a change are slim. Neurath would not only concur, but stress the fact that all of science is in the same boat. The physicalism which he recommends (he is the inventor of the term) is a plea to all of the sciences to use a common language, one which is "nothing new as it were; it is the language familiar to certain 'naive' children and peoples".[8] As Haller comments, the physicalist language is nothing but "the everyday language of the 'natural conception of the world'", the last expression being due to Avenarius, the founder of empiriocriticism, a major influence on Neurath.[9] No doubt Neurath would find the naturalistic worries of Fodor and his contemporaries misplaced, but this is another story. The main point is this: if Neurath's insight is correct, as I believe it to be, then the epistemic purity requirement can never be met, except perhaps in very special cases, which are at any rate unlikely to be encountered in the context of the sciences of man.

[8] Neurath 1932: 66; quoted by R. Haller, in Uebel 1991: 195.
[9] Haller, *ibid.*

John Dupré has mounted a book-length attack on the other requirement[10]. Of course, it was never a secret that some phenomena occur at the intersection or the interface of different realms. Neurath's own preferred example was that of the forest fire: how can we predict when a given fire will be extinguished? Neurath plausibly argued that an answer would require the resources of botanics, meteorology, geography, sociology, various technologies, and today we might add ecology. It has never been a mystery that the same fragment of stuff can be a piece of clay, a statue, a religious symbol, an architectural support, a tool for crushing an infidel, etc. However, the thought was, physics has managed to ignore these cases: it does not deal with forests or statues, fires or religious wars. Pure science is precisely dependent for its existence on the exclusion of hybrid entities, which are the business of engineering and applied science. What Dupré argues is that far from being marginal, membership in a plurality of natural kinds is typical; this is the view he defends under the label of 'promiscuous realism', a doctrine which combines an ontological commitment to natural kinds and a rejection of the uniqueness condition. There *are* natural, agent-independent boundaries in nature, but these boundaries criss-cross, and there is no fact of the matter as to which is *the* correct affiliation of a given entity. Although there is a fact of the matter as to which affiliations are *incorrect*, the choice of *a* correct affiliation is context- and purpose-dependent. No doubt this is not easily acceptable from a classical standpoint, whether in philosophy of science or metaphysics, or in science itself. *Hybrid entities* went unrecognized for a long time in the 'noble' sciences. Take culture: surely its elements are collective representations, a self-standing ontological category? That is certainly what we were taught to believe. But if instead one considers something like Dan Sperber's epidemiological theory[11], one sees culture as a collection of distributions of mental and material representations in a human population, just as an epidemic is a distribution, causally produced by contagion or other replicating mechanisms, of clinical states induced in human or other animal populations by micro-organisms or other pathogens. Given a mental representation in one particular human mind (John thinking today about whether to vote for Sarkozy), it naturally belongs to a kind of brain state, to a kind of psychological state, to a kind of cultural phenomenon. Ecology, meso-physics and countless other recently developed research programs provide further examples, but one also realizes, in retrospect, that past scientific developments are no less rich a source. Once one starts to look for cases of multiple affiliation, one finds so many that one gets to wonder if single affiliation is anywhere to be found, except in particle physics.

But if something like Dupré's account is true, how can we account for the late realization of this state of affairs? The answer, I submit, is this. First, experience teaches us a number of reasonable taxonomic choices; faced with a theoretical problem, we are guided by previous situations which are similar in appropriate respects. This is not a failsafe strategy: it works, well, exactly in those cases where it works; experience insures that such cases are frequent- how this is achieved is a notoriously difficult question, but one which is not specific to our present concern and which is not generally regarded as entirely hopeless. The second part of the answer lies in a cultural strategy which is the cognitive version of niche construction, a well-documented phenomenon related to co-evolution of species, recently extended to the study of interactions between biological and cultural evolution[12]. The conjecture is that we tend to collectively create a world, part epistemic, part institutional, part material, in which our scientific tasks are on average less awesome than they would otherwise be; this, if correct, would amount to a process of unsupervised collective learning. The better we become, as individuals and as members of scientific communities, at handling taxonomic underdetermination, the less we see that there is an underdetermination in the first place.

Hybrid concepts and sortal pluralism are the first potential objection to classical unitarian or regionalist views.

The Myth of Completeness

I now come to a second objection, which is less discussed perhaps because it is too obvious, or, more likely, because it runs counter received opinion. Neurath, as I discovered recently, had put his finger on it already. The starting point is a trite observation: at any

[10] Dupré 1993.
[11] Sperber 1996.
[12] Laland 2000; Sterelny 2003; for a related approach, Richerson and Boyd 2005.

given moment of time, the knowledge which any knower, any community of knowers has of a chosen realm is incomplete. It is usually tacitly assumed that this incomplete body of knowledge is bound for completion, be it in the indefinite future: let us call this the *completeness in the limit assumption*. It is also thought that that there comes, in any science, a time of maturity in which our knowledge far exceeds our ignorance, so that we can assume in such cases that we have achieved a state close to a full knowledge of the topic at hand. This latter, *near-completeness-in-practice assumption* is prevalent and it bolsters the case of the former, completeness-in-the-limit assumption. Even in our post-positivist age, one hears references to an 'ideally completed physics', or 'neuroscience'; philosophers talk of counterfactual situations where someone would know 'all there is to know' about some area or system. Commonsense and scientific practice, as well as history of science, seem to endorse both assumptions. And indeed, isn't it obvious that in more than a few areas we do possess all the knowledge worth having? Take just about any branch of physics or chemistry which is taught in schools and used in technology and engineering, with the notable exception of quantum mechanics: aren't those instances of near-complete knowledge? What about large parts of medicine, such as anatomy, physiology, ophthalmology? And our practical knowledge of, say, everyday economics (how do deal with money, banks, checks, bills...) or public transportation in the city where we live is also clearly complete or very nearly so.

Although a full discussion can't be offered here, it is important to see why these intuitions are misleading. Neurath had a general argument against what we could name the Myth of Completeness. Throughout his career, he was scathing in his criticism of what he called 'pseudorationalism', the overconfidence in rationality as a kind of universal insurance policy against uncertainty and error. He writes for example:

> Pseudorationalism will time and again try to reach, in roundabout ways, the 'one *real* world' ('the *one* mass of statements distinguished by certain characteristics'), for example, by putting forward the doctrine of a perfection, perhaps 'infinitely far away' to which science gets closer and closer.[13]

I won't attempt an analysis of the Neurathian theme of pseudorationalism. I will instead suggest, in what I hope to be the same spirit, an answer of my own. It might be thought that the problem is the fallibility of knowledge, at least in scientific theorizing. But we have I think learnt not to overextend Popper' conjecturalism or Laudan's pessimistic induction: in many fields, we are in fact not expecting that our current theories will one day be proved dramatically wrong; we do not expect that a new fact will force us to simply discard them; at worst, they might require a reformulation. The problem lies elsewhere and is directly connected to the issue of boundaries which is at the heart of our present concern. What we can *not* be confident about are the boundaries of the domain of which we feel confident that we have complete or near complete knowledge. These boundaries may well suddenly burst open under the pressure of a new discovery, or a theoretical insight such as Maxwell's, when he noticed that the velocity of electromagnetic waves as he had just computed it came very close to the velocity of light. Light in fact provides an amusing example of the false security we sometimes feel regarding our state of knowledge. This is what Priestley wrote in 1772:

> ...the nature of vision, in general, seems to be very well understood ; and there are few phenomena belonging to it that have not been satisfactorily explained.[14]

It is not necessary to be informed of the latest advances in vision science in order to realize the depth of Priestley's ignorance. What he did not know, for the most part, does not pertain to aspects of vision which he and his contemporaries were aware of. We can even safely assume, for the sake of the argument, that what they knew at the time has been on the whole confirmed rather than disconfirmed by later developments. Rather, what Priestley did not know regards what was later shown to be *relevant* to a fuller understanding of vision (such as the complex cognitive operations performed by the visual cortex on the deliverances of the optic nerve). In other words, what Priestley did not know is what one should have knowledge *about*, beyond the domain about which he did have considerable

[13] Neurath 1936, in Neurath 1983: chap. 11, p. 137.
[14] Joseph Priestley, *History and Present State of Discovery Relating to Vision, Light and Colours*, 1772.

knowledge. A similar example is making the headlines as I write: the discovery of the role of RNA is shattering the illusory near-completeness which molecular biology was claiming until recently as regards the genetic line of command to the cell. What I am arguing for here is a form of conjecturalism, but applied to questions rather than answers as in Popper's doctrine.

We are now in a position to see why the near-completeness that we are prone to grant to certain bodies of scientific knowledge is either illusory or trivial. Yes indeed, in such cases we have the answers to all the questions on a list which we have made up; we have become unsurpassable experts of the domain *as we have defined it,* as the domain of which we are unsurpassable experts. Unfortunately for the pseudorationalists among us, it may well turn out that tomorrow's list of questions will go far beyond, or indeed be quite different from our present list.

This leaves us, as for the Myth of Purity, with a puzzle: Why is the Myth of Completeness so persistent? The answer may lie in a residual Cartesianism which still forces on us the mathematical ideal. In mathematics, there is such a thing as complete knowledge, or so at least it may be argued. Once a domain is fully axiomatized, the set of consequences of the axioms constitutes the complete knowledge of the domain, whether we are now, tomorrow or never able to determine all of these consequences. Unpurged Cartesianism may lead us to extend this view to empirical knowledge.

To conclude, let us make sure we understand why the necessarily partial character of our knowledge undermines the classical unitarian or regionalist views of science. For regionalism, either traditional or functionalist, the case is clear: on the partial knowledge view, there are no stable boundaries in science. For unitarianism, the argument is less direct. There is moderate form of unitarianism which is not only compatible with, but encouraged by the partial knowledge view, and which I will in fact defend below: if there are no non-arbitrary boundaries to be found, the default assumption is that of science as one large set of variously connected, diversely entrenched bodies of knowledge, forming perpetually changing configurations. On the other hand, the classical form of unitarianism seems to be wedded to the metaphor of the 'complete picture' of an organism-like nature as described in the Poincaré quote above, a picture of which we would gradually uncover bits and pieces, as if we were involved in doing a gigantic puzzle, in *re*constituting a whole from fragments, in putting Humpty Dumpty together again. This entire scheme, which has been challenged by several authors[15], is wedded to the Myth of Completeness, and thus ceases in the partial knowledge perspective to be coherent or useful.

Generalized complementarity

I now come to my third and final attack on (strong) unitarianism, based on a recent proposal by Rom Harré[16]. We may perhaps take again Neurath as starting point. He writes: "Very often scientists know perfectly well that certain principles applied to a certain area are very fruitful, while contradictory principles applied to a different area also appear to be fruitful".[17] Neurath has in mind such examples as Newtonian vs relativist dynamics, and he believes this situation to be frequent rather than exceptional. This is Harré's strategy as well, although he probably was not inspired by Neurath. More radically than him, he considers the case of a single domain. Bohr's complementarity principle applies to the domain constituted by a single electron, which can be subjected to two kinds of measurements. One kind of measurement will yield a precise value of its velocity, but make it definitively impossible to find out its momentum, and another kind of measurement will do the reverse. Harré claims that this is not restricted to the quantum world, but extends to large areas of knowledge.

The wave/particle dual nature of light provides another arcane example: when we submit a ray of light to a certain type of experimental set up, it reveals its corpuscular nature while its ondulatory potential is definitively lost; in a different type of set up, the situation will be reversed. Harré offers examples of a very different sort. The same individual, in a psychiatric ward, will turn out as a mental patient; in the dark of night, as a sadistic brute; in court, as a criminal in the legal sense. A given passing thought, from a phenomenological or introspective perspective, is revealed to the agent as a manifestation of her self; it is shown to be a feature of a cerebral state to the operator of an fMRI scanner. The crucial point is that

[15] See in particular van Fraassen 1999, which I discovered unfortunately after preparing the present paper.
[16] Harré 2006, Andler 2006.
[17] Neurath 1946: 498.

these pairs of traits cannot be revealed simultaneously: any procedure needed to reveal one forbids the deployment of a procedure which would reveal the other. Harré's formulation is as follows. A *determinable* is a predicate variable, which can take on one of a number of values when applied to a given entity; so that, for example, *color* is a determinable which, for a cherry, takes on the value Red. Complementarity arises when two distinct determinables cannot be attributed to the same object at the same moment. Cherries do *not* generally give rise to complementarity: their color and shape, for example, can be attributed to them simultaneously; nothing in an operation required to ascertain their color will compromise a simultaneous attempt to determine their shape. By contrast, a given game of rugby, when played by the players, makes accessible to them some features which are forever inaccessible to the physiologist; the measurements which the physiologist will make to determine various parameters of the bodies in play require a set-up which is incompatible with the lived experience of the game. A given moment of spiritual bliss can either be known as such to the enlightened person, or known as a neurophysiological event, but cannot be known as a phenomenon which is both spiritual and neurophysiological.

The intuition which Harré wants to tap, I think, is that consilience, "the linking together of principles from different disciplines, esp. when forming a comprehensive theory"[18], sometimes runs into the impenetrable wall of complementarity: no theory can be expected to actually link organically, intelligibly certain kinds of properties concerning one and the same entity. This may be a brute fact, or one may perhaps connect it with certain features of our epistemic situation, or with the grammar of our language. Probing Harré's idea and the more general idea of the limits of consilience will have to wait for another occasion. But *if* there is such a principle as Complementarity or Limits to Consilience, *then* clearly the classical, strong unitarian conception is bankrupt, for it rests, as we saw, on the notion of a self-interpreting picture, one with a single, transparent, immediately accessible meaning. Harré's principle implies that even at the most local scale, at least in some (non exceptional) situations, the 'image' provided by science is never at once the whole picture: rather like a hologram, it changes according to the angle of view.

3. Combining unity and plurality: federalism as description and prescription

Problems such as these, adding to the enduring divided condition of science, have encouraged the swing of the pendulum towards a new orthodoxy: the program now is the Disunity of Science. The problem of course is that it's not much of a program. The world is 'dappled', all coherence is gone, and the most we can do is let scientists do their job, which is to sort things out locally as best they can.

There are two things lacking in this 'realistic' perspective. One is a proper consideration for the awesome progress which by universal agreement is accomplished every time a genuine unification is offered. The idea of biological evolution conferred to the life sciences a degree of unity, or cohesiveness, which was simply unthinkable after the demise of the mechanistic program and before Darwin. The microbial hypothesis united pathology to a very large extent. The Faraday-Maxwell theory of fields brought together an enormous part of the physical sciences. The utility-maximizing hypothesis (regardless of its imperfections) has brought unity to micro-economics. Group theory has unified not only parts of mathematics, but of chemistry as well, and of morphogenesis. Particle physics may be on the eve of a grand unification which some of its promoters see as nothing short of miraculous. Now the real difficulty lies surely not in noticing that science is in fact a rather unruly mass, but in accounting for these transformations, as well as the smaller-scale unifications which occur all the time, increasing the density of the links between the countless branches of science.

The second shortcoming of the Disunity position is that it can encourage a form of separatism which is the natural trend imposed by scientific institutions and other social, economic and psychological factors. Let us recall that Neurath's main motivation for promoting Unity of Science as a program was to prevent the sciences of man from claiming immunity from the critical look of other fields. His proposed cure was *not* to promote an

[18] Merriam-Webster Dictionary.

unrealistic and dangerous blanket unification, but to make it possible for all fields to enter in a critical dialogue by providing them with a common language.

In a similar spirit, I would like to promote a federalist conception of the Republic of Science. My starting point is a minimal form of naturalism–nothing more than an acknowledgment of our epistemic engagement in nature, by means of common experience as well as the scientific enterprise, the two modalities being deeply intertwined. This naturalism is realistic in spirit: our engagement is both a cause and a symptom of some rough fit between nature and our ways of thinking about it. Therefore, the fact that nature still looks to us, not at first sight, but after more than three millenia of persistent inquiry, as orderly and disorderly at once, as somewhat homogeneous and somewhat heterogeneous, is to be taken as sufficient reason to discard both unitarianism, whether reductive or organic and its kin, classical and functionalist regionalism. Both camps suffer from inductive delusion: they extrapolate past experience to the day of the Last Judgement, when the Picture will be complete, and exhibit one or the other structure which they see emerging at present, disregarding the historical fact that the partial pictures at successive stages do not simply get gradually filled in, but sometimes undergo drastic restructuring. A second mistake is to ignore the imperfect character of two of the key operations at work in unification, reduction and filtering. A model of the first is provided by statistical mechanics, which is alleged to reduce thermodynamics to microphysics (another model is the reduction of chemistry to physics by way of quantum mechanics). There are two kinds of difficulty in such cases. First, they do not obviously fill the bill to perfection: the debates are still going on, and turn on the question of a remainder–does the reducing theory account for absolutely everything the reduced theory explains? if so, does it not help itself to exogenous hypotheses? But second, these cases of reduction, whether perfect or nearly so, are at any rate the exception rather than the rule among reductions. The average reduction leaves a quite visible remainder. Filters have problems of their own: the 'lower', screened-off level 'shows' through the screen; more often than not, it turns out to be impossible to leave the filter in place all the time–it has to be removed once in a while.

All of which, of course, is grist to the mill of the 'anarchist' anti-unitarians. But they in turn tend to exaggerate the chaos and recurring upheavals in science, and much recent work tends to show that appearances notwithstanding, important cores–structural or other– in established scientific knowledge resist theory change[19].

By proposing federalism as a metaphor for the overall structure of science, I try to accommodate the core intuitions of all sides. Unitarians are right to regard unification, by whatever means, as an essential goal of science: it is a permanent feature of science on the move, and an irreplaceable source of progress. Regionalists are correct in detecting some permanence in the division of explanatory labor (whether or not this division is based in some boundaries in nature itself). Anti-unitarians rightly stress the disorderly, profuse and ever changing connectivity between the countless areas and subareas of science. Federalism grants some unity, some stable division, and some permanent reconfiguration at the local and global levels, and in the relations between the two.

As a descriptive stance, federalism can thus perhaps claim to be the most realistic of the contenders. But it also has merits as a prescriptive stance. Neurath borrowed an expression used by H.M. Kallen's at the Fifth Congress for the Unity of Science, which was held at Harvard in 1939: the 'orchestration of the sciences'[20]. He meant it first in an 'anti-totalitarian' sense. To him, the attempt, by philosophers past or present, to erect a 'system' of science, was both misguided and sinister. What was called for, by contrast, was the free circulation of ideas between the disciplines. Better, they should be put in mutual resonance, without in any way one imposing its order on the others: the diversity of the sciences was to be preserved above all. Orchestration was needed, though, to overcome the state of dispersion caused by specialization (Comte had a similar worry, but sought the cure in universal education by 'scientific generalities'). Dispersion soon leads to separate development, each science becoming an autonomous fiefdom accountable only to its own subjects. The resulting situation, in Neurath's eyes, ran clearly against the higher goals of

[19] Poincaré was the first to call attention to structural invariance, and to use it as an antidote to what was not yet known as the pessimistic induction (Poincaré 1902, chap.X). For another kind of invariance, see Mayo 1996.
[20] Neurath 1946, in Neurath 1983, chap. 22.

human learning, and encouraged instead noxious forms of irrationality. Orchestration was meant as a way of inviting a fruitful dialogue.

But who, we may ask, stands at the pulpit? Not physics (the tempting answer in Neurath's time), not biology (the temptation today), nor philosophy, or history. The metaphor, I contend, holds water only if subverted. Nature takes the pulpit, and the musician-scientists oscillate between their score (standing for the tradition and problem situation of their discipline) and nature, which distributes the emphasis and tempo to the orchestra. The scientist (or the scientific community she belongs to) sees Nature with one eye, its partial representation with the other, and the fusion of the two affords an ever-changing three-dimensional image of the object of inquiry. Each scientist simultaneously perceives, through her peripheral audition, the parts of (some of) the other scientists, and modulates accordingly her own play, while interpreting the conductor's 'indications'.

This admittedly stretched metaphor is only meant to convey the idea that scientific knowledge really emerges not from the mechanical adjustment of the pieces provided by the various sciences (although such adjustments do happen), but from a polyphony of inquiries disciplined by critical debate.

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