Ontic Structural Realism, Information, and Natural Necessity: Where Naturalism and Analytic Metaphysics Can Find Common Ground

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April 12, 2013

J. Ladyman (1998-2009), Ladyman and Ross (2007) refine J. Worral's (1998) structural realism (SR), by developing an ontic structural realism (OSR) which they argue is a consistently naturalistic means of characterizing the ontology of fundamental physics. I argue that elements of analytic metaphysics strengthen and refine their project of characterizing fundamental physics via OSR and by extension, their presentation of information-theoretic structural realism (ITSR). I refine this point by situating M. Lange's (2009) discussion of nomological modality *qua* natural necessity within Ladyman and Ross's discussion of ITSR. The logical hierarchy evinced in Lange's (2009) 'nomic stability' further extends and refines Ladyman and Ross's claims through the addition of nuanced modal distinctions in a systematic framework.

1. Wherefore 'Ontic' in Ontic Structural Realism (OSR)?

'Structural realism' (SR) was explicitly coined by John Worrall (1989), in an attempt to develop a plausible rendition of scientific realism immune to the 'inflationary metaphysics' to which typical versions are often vulnerable.[1] *Eo ipso*, SR's aim would also avoid the 'indexical anthropocentrism' some might see as problematic with scientific non-realism.[2] 'Roughly speaking, structural realism is the view that our best scientific theories describe the structure of reality, where [*contra* non-realism] is more than saving the phenomena, but [*contra* scientific realism] less than providing a true description of the natures of the [putative] unobservable entities that cause the phenomena.' (Ladyman and Ross 2007, 67)

Moreover, it bears emphasizing that SR was developed in response to the problem of theory-change or (in some cases) radical conceptual change, by far the most difficult problem

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confronting the scientific realist. 'Theories can be very different and yet share all kinds of structure…Hence, a form of realism that is committed only to the structure of theories might not be undermined by theory change…The most minimal form of [SR]…is best thought of as a defence of the cumulative nature of science in the face of Kuhnian worries about revolutions.' (Ladyman 2009, 6) Indeed elements of structural realism are present, at least in implicit form, in much Western philosophical, mathematical, and scientific literature dating as far back as Aristotle.[3]

1.1 *What is Wrong with ESR*

J. Ladyman (beginning in 1998) distinguishes *epistemic* from *ontic* structural realism (ESR versus OSR)**,** arguing that both notions are often mistakenly conflated in Worrall. I will make passing mention to ESR, briefly summarizing (according to Demopoulos and Friedman's 1985) critiques) why the position is oft considered untenable. According to ESR, all one can ever fundamentally *know* about the physical world reduces to the level of structure—whether (weakly construed) that comprises *au fond* (unknowable) individuals' intrinsic properties, or (strongly) only the second-order relational structure of otherwise unknowable individuals and their properties. For example, (Carnap 1929 and Russell 1911 held fast to the latter notion—as evident in Russell's logicist metaphysical thesis: '[S]cience only tells us about purely logical features of the world …[since] we know only the (second-order) isomorphism class of the structure of the world and not the (first order) structure itself.' (Ladyman 2009, 7).

Demopoulos & Friedman's (1985 criticisms of ESR can be viewed as following in spirit Newman's (1928) objection to Russell (1911),[4] and to a closer logical letter. According to the syntactic view, a theory Π may be regimented into some first-order formal syntax (FOL) such

that: $\Pi(o_1, o_2, ..., o_m; t_1, t_2, ..., t_n)$ where Π is the theory's *sentence* in the FOL, and $o_1,\ldots,o_m$ are the *observation terms* and $t_1,\ldots,t_n$ are the *theoretical terms* in Π.[5] As Ramsey (1929) originally showed, one can formulate Π in this FOL by quantifying over its theoretical terms by way of constructing its *Ramsey Sentence R*:

$$\Pi(o_1, o_2, ..., o_m; t_1, t_2, ..., t_n) \xleftrightarrow{\text{'Ramsification'}} \exists x_1 \exists x_2 ... \exists x_n R(o_1, o_2, ..., o_m; x_1, x_2, ..., x_n)$$

What is important to keep in mind is that the above procedure does *not* eliminate the (unobservable) theoretical 'vocabulary': '[T]he Ramsey sentence only asserts that there are some objects, properties, and relations that have certain logical features, satisfying certain implicit definitions…*it is a mistake to think that the Ramsey sentence allows us to eliminate theoretical entities*…It is just that they are referred to not directly, by means of theoretical terms, but by description…via variables, connectives, quantifiers and predicate terms whose direct referents are (allegedly) known by acquaintance.' (Ladyman 2009, 8). Hence one can think of the Ramsey procedure as the logical machinery underwriting ESR—Russell certainly did.

As Demopolous and Friedman (1985) further clarify: If Π is logically consistent (in the FOL) and all its observational consequences are true, then the truth of its Ramsey sentence *R follows as a theorem of set theory or second-order logic* (so long as the initial domain of referents is characterized by a set of the proper cardinality). In other words, the formal structure cannot single out a unique referent, so 'only cardinality questions are open to [empirical] discovery, everything else will be known *a priori.*' (9) If only the cardinality of the set of observation-terms can be fixed *a posteriori*, then all theories with the same set of observational consequences will be equally true. Hence (*a' la* Neumann's objection) 'Russell's realism collapses into a version of phenomenalism or strict empiricism.' (Demopoulos and Friedman 1985, 635).

In accords with the semantic view, 'the Ramsey sentence of a theory and the theory itself are importantly different.' (Ladyman 2009, 10) At best Ramsey sentences pick out entities in such a manner that the referents of theoretical terms become functions of the place such terms hold in the theory's logical structure, 'so simply adopting Ramsification may actually make the problem of ontological discontinuity even more acute.' (10). Hence, 'structural realism should be thought of as *metaphysically*, rather than merely *epistemically* revisionary.' (ibid., emphases added).

1.2 *The Alternative: OSR*

A position that 'most physicists advocate' (whether implicitly or otherwise), OSR's claim is that the physical world *is* ultimately individuated by some species of structure: 'Ontic structural realists argue that what we have learned from contemporary physics is that the nature of space, time and matter are not compatible with standard metaphysical views about the ontological relationship between individuals, intrinsic properties and relations…broadly construed OSR is any form of structural realism based on an ontological or metaphysical thesis that inflates the ontological priority of structure and relations.' (Ladyman 2009, 11)

Ladyman (2009, 11-21) subdivides OSR into a total of seven different positions, of varying degrees of metaphysical strength or tendentiousness, as summarized below.[6]

OSR-1: There are *no individuals*, there is only *relational structure*. For example, certainly universals (*a' la* Platonism) 'presuppose formal properties that are independent of the contingencies of [their] instantiation…To say that all there is are relations and no relata, is perhaps to follow Plato [further] and say that the world of appearances is not properly thought of as part of the content of knowledge.' (11).

OSR-2: There are *relational facts* and *relations* that *do not supervene* on the intrinsic spatiotemporal properties of relata. Although this runs counter to a 'deeply entrenched way of thinking'—since structure of often characterized set theoretically or logically (upon which all relational structure therefore trivially supervenes)---'[A]dvocates of OSR[-2]…emphasize the non-supervenient relations implied by quantum entanglements undermine the ontological priority conferred on individuals in most traditional metaphysics.' (13).

OSR-3: Individual objects have *no intrinsic natures*. An example of this position is described by Parsons (2008) as an example of 'eliminative structuralism' in the case of mathematical objects. To say, for example, that numbers have no 'intrinsic nature' is to claim that numbers reduce entirely to 'external' partial ordering relations characterized in terms of some abstract structure, determined recursively by the Peano axioms, etc.[7]

OSR-4: There are *individual entities*, but they have *no irreducibly intrinsic properties* denoted as a 'moderate OSR,' in which 'all the properties of individual objects are ontologically dependent on the relational structures.'[8]

OSR-5: *Facts* about identity and diversity of *objects* are *ontologically dependent* on the *relational structures*, of which they are a part. Ladyman (2008, 2009) refers to this position by arguing that there are cases (in quantum spin statistics—e.g. Bosons versus Fermions) in which the identity and diversity of the objects in a structure (the statistical ensemble, in this case) is a primitive feature of the structure as a whole: Fermions are individuated via the Pauli Exclusion Principle, whereas Bosons are not.

OSR-6: There are *no subsistent objects***,** only *relational structure is ontologically subsistent*.[9]

OSR-7: Individual objects are *epistemic constructs*.[10]

All seven different versions of OSR incorporate the ramifications of some of the most successful physical theories- quantum field theory (QFT), General and Special Relativity (GR and SR), quantum chromodynamics (QCD), quantum topology, etc., as suggesting metaphysically a view of the world which calls into question the 'traditional' metaphysical world-picture. (Ladyman and Ross 2007, 1-129) expand upon this point by attacking contemporary analytic metaphysics.[11] To this extent, one can view OSR as calling attention to a central problem involving *the individuation of objects*, by the metaphysical lights of some of our best theories in physics:

> There is no unanimity about the difference between individuals, objects, and entities among philosophers *but one neutral way of putting the issue is to ask whether there are only individual objects* in the logical sense…as the value of a first-order variable, or whether there are individuals in some more substantive sense (for example, being subject to laws of identity, or being substances). (Ladyman 2009, 12)

Ladyman and Ross (2007, 130-258) deny the above question. In their chapter on fundamental physics, a host of positions are surveyed[12], through the primarily operative category of *information* (whether conceived classically—e.g., Shannon-Weaver, or quantum mechanically—e.g., von Neumann). In particular:

> Information is apt for characterizing QM [quantum mechanics] because it is a modal concept…The world is not made of anything [understand in the classically metaphysical substantival sense of a primitive atomistic ontology] and information is a fundamental concept for understanding the objective modality of the world, for example, laws, causation, and kinds. (Ladyman and Ross 2007, 188-189)

Indeed, *objective modality* is what evinces OSR to be a rendition of scientific realism[13]—minus the ontological commitments of standard versions of scientific realism, i.e. insofar as the latter assent to the truth-conditions characterizing the semantic reference of the (unobservable) content of a theory's central terms.[14]

2. Information and OSR

The metaphysical burden of developing an account of individuals, causation, and laws *qua* the special sciences from the OSR framework characterizing fundamental physics is taken up by Ladyman and Ross (2007, 190-297). 'If fundamental relationships in physics are described by symmetric mathematical relations…the same surely cannot be said of the most important generalizations in biology or economics. Even if quantum entanglement is thought to undermine individualism in fundamental physics, it is generally thought not to 'percolate upwards' into the domains of the special sciences.' (196) By the lights of OSR:

> [T]o present the ontology of the world according to, for example, GR [general relativity] one would present the apparatus of differential geometry and the field equations and then go on to explain the topology and other characteristics of the particular model…that is thought to describe the actual world. There is nothing else to be said…Mathematical structures are used for the representation of physical structure and relations, and this kind of representation is ineliminable and irreducible in science…This may suggest a kind of Pythagoreanism, asserting the identity of structures in mathematics and physics and abandoning the distinction between the *abstract* structures employed in models and the *concrete* that are the objects of physics. [It is thought that] [t]he canonical substance in physics is matter, but matter has become increasingly ephemeral in modern

> physics…Moreover, the dependence of physics on ideal entities (such as point masses and frictionless planes) and models also offers another argument against attaching any significance to the abstract/concrete distinction. (159-160)

Information is viewed as the operative category here, in terms of collapsing the epistemic distinction of abstract versus concrete and the ontological distinction of substance versus form. In particular, as suggested in the passage above on objective modality, the authors argue for an 'information theoretic fundamentalism,' which (echoing Zeilinger) in a deflationary sense renders impossible any operational distinction to be made between reality and information. (189)

2.1 *Two Central Principles: Naturalistic Closure (PNC) and Primacy of Physics (PPC)*

To safeguard this information-theoretic fundamentalism from reducing to the thesis that the world is constituted by some new substance, (i.e., 'infostuff', suggestive of the traditional metaphysical enterprise of characterizing the world in some kind of a compositional hierarchy[15]) two central methodological principles secure the project as a *naturalistic* endeavor:

> **Principle of Naturalistic Closure (PNC)**: A metaphysical claim to be taken seriously at time *t* –i.e., if the claim is accepted as true at time *t*—should only be motivated by showing how two (or more) fundamental hypotheses (at least one such hypothesis drawn from fundamental physics) can jointly explain more than the sum of what the hypotheses can explain, when taken separately.[16]

> **Primacy of Physics Constraint (PPC):** Hypotheses in special sciences that conflict with the consensus in fundamental physics 'should be rejected for that reason alone.

Fundamental physical hypotheses are not symmetrically hostage to the conclusions of the special sciences.' (Ladyman and Ross, 2007, 44)

The PNC and the PPC act as constitutive and regulative principles for a metaphysics naturalized, i.e. a discipline in which 'networks of consilience' (Whewell) are established across the specialized sciences, constrained appropriately by the PPC. Adopting the PNC and PPC suggests a Peircean verificationism,[17] in which methodologically one cannot draw any principled distinction between fundamental physics and metaphysics. (45, n.45) Naturalistic metaphysicians' claims differ only in a manner of degree with those of scientists, since (meta-methodologically speaking) there is no monolithic 'scientific method' simpliciter. (28) Instead, 'specific institutional processes [insofar as they're delimited by the PPC] of science have inductively established peculiar epistemic reliability.' (37) In short, their metaphysic synthesizes elements of constructive empiricism and a scientific realism based on 'broadly Peircean verificationism.' (67)

Naturalistic metaphysics, then, utilizing the PNC and PPC underwrites OSR as a species of information-theoretic (*not* 'infostuff') fundamentalism: '[A] practicing physicist entertains the idea of modal structure ungrounded in substances and natures of fundamental entities is…PNC-compatible evidence that OSR should be taken seriously despite its incompatibility with the intuitions fostered in philosophers by the combination of parochial demands placed on our cognition…and an education in the classical texts of metaphysical tradition.' (188)

3. A Role for Analytic Metaphysics to Play in OSR

Predictably, Ladyman and Ross (2007) did not escape the notice of some contemporary analytic metaphysicians. In particular, Cian Dorr (2010) comments:

> In rejecting the modes of argument they see as characteristic of analytic metaphysics, the authors…have, I fear, also cut themselves off from the techniques analytic metaphysics has developed for stating claims clear and explicit enough to be worthy targets of argument…This is a great pity, from the point of view of anyone who shares the authors' belief that analytic metaphysics has much to learn form a more informed engagement with modern physics and philosophy of physics. (8)

Hawley (2010) phrases her criticisms more charitably:

> [T]hough the details are new, they fit into a venerable tradition of anti-metaphysical thought stretching back through the logical positivists to Hume…it is striking that this challenge is not the methodological issue which most preoccupies metaphysicians right now. (1)…[T]he literature of contemporary analytic metaphysics contains a *wealth of resources, distinctions and concepts which the authors might profitably have used in developing and setting out*…their views, even if just by way of contrast. After all, one standard, very modest view of the role of philosophy with respect to science is that of conceptual clarification. (5, italics added)

While Dorr (2010) appears to repudiate the work on the grounds of its *contents*, Hawley's (2010) approach focuses more on the *form* and *methods* the authors employ. I ascribe to Hawley's worry and develop a constructive case involving information *qua* modality to extend her points. Prior to this, however, one may respond to Dorr's complaint as a being non-starter. Dorr's standards of clarity and explicitness, one may gather, are somewhat discipline-specific, and to that effect, tendentious. However, Ladyman and Ross (2007) already remark at the outset:

> There is a rich tradition of naturalistic metaphysics in Western philosophy. Competing strongly…is a tradition which aims at domesticating scientific discoveries so as to render them compatible with intuitive…pictures of structural composition…Such domestication is typically presented as providing 'understanding', [a] usage…given [an] everyday sense…[of] 'rendering more familiar'. However, we are interested here in a sense of 'understanding'…better characterized by the term 'explanation'…[In contrast] a given metaphysic's achievement of domestication furnishes no evidence at all that the metaphysics in question is true, and thus no reason for believing that it explains anything. (1-2)

To slightly re-phrase the above point: '[I]maginability must not be made the test for ontology. The realist claim is that the scientist is discovering the structures of the world; it is not required in addition that these structures be imaginable in the categories of the macroworld.' (McMullin, 1984, 14).

3.1 *Information and Modality*

As briefly mentioned in the first section, OSR's commitment is toward objective modality. Ladyman and Ross (2007) recognize the latter's connection with information-theoretic fundamentalism: 'Information-processing, like information, is modal.' (189, n.189) Moreover, their naturalism, as directed by the PPC and PNC, recognizes only nomological modality:

> For 'modal' read 'nomological' if you like. We do not take it to be 'causal structure' [as]…causal structure is the pragmatically essential proxy for it in the special sciences (but not fundamental physics). (130)

> [W]e are motivated [by]…the PNC to take seriously the world is structure and relations. Individual things are locally focused abstractions from modal structure. By modal structure we mean the relationships among phenomena (tracked or located…as things, properties, events, and processes) that pertain to necessity, possibility, potentiality, and probability. (153-4).

Echoing Hawley's (2010) appeal to the repertoire of 'resources, distinctions, and concepts' includes, I submit, a more fine-grained articulation of modality, as often encountered in analytic metaphysics.[18] For instance, one may consider metaphysical modality as logical modality (which Kripke (1980) argued are coextensive), and epistemic modality.[19] Do the latter bear any relevance to OSR as conceived naturalistically?

Ladyman and Ross (2007) state 'there are no entities in the material mode…merely the world and its real patterns [and]…we will use informational concepts to define these real patterns.' (186) They refine Dennett's (1991) latter notion[20] to develop a consistent notion of scale-relative ontology such that a plausibly unified picture (modulo the constraints of the PPC) can support a principled distinction between fundamental physics and the special sciences.[21] 'A 'real' pattern, Dennett (1991) argues, must admit of capture using a smaller number of bits of information than the bit-map transcription of the data from which the pattern could be computed.' (202) Now, as the authors admit, 'the central concept in our theory of ontology, 'information', has multiple scientific interpretations (and goodness knows how many philosophical ones).' (210) Nevertheless, to account for a theory of ontology, 'that is, a theory which makes explicit the metaphysical claim made by saying of some *x*, in a context where metaphysics governs the intended contrast class, '*x* exists'' the sense of information as *logical*

depth or algorithmic compressibility is the appropriate property of 'structural models of real patterns.' (220)

This notion of information *qua* logical depth constitutes their theory of an objective measurement in the abstract, which is adopted in their 'rainforest realism' (220-238) or 'information-theoretic structural realism' (ITSR, 238-257)—the latter being the extension of the domain of OSR to account for the special sciences. This general and abstract notion of information content necessarily comprises part of OSR's characterization 'of the modal structure of the world as manifest in regularities [and]…why regularities are the basis for something fit to be called modal structure.' (221) Nevertheless, information as *thermodynamic depth* (i.e. the minimum quantity of entropy produced for the evolution of a state) is likewise reserved 'in discussion of special [e.g. biological] systems,' since '[s]ketching possible empirical relationships between…these two ideas [logical depth, thermodynamic depth] is how we respect the PPC.' (218) Moreover, in the context of fundamental physics, *quantum information* with its associated ambiguities of theoretical status[22] nevertheless occupies a central position in OSR 'because it is a modal concept.' (188)

Do all the above notions of information reduce to nomological modality? I maintain that they do not. Information as *logical* depth connotes a notion of *logical* modality: Recall that the distinction between fundamental physics and the special sciences is based *a priori* on the notion of scale and location-independent measurements made by the former and not by the latter: '[T]here are some real patterns about which measurements taken *anywhere in spacetime at any scale of measurement* carry information (in the logical, not thermodynamic, sense). Fundamental physics is that part of institutional science responsible for trying to discover maximally redundant real patterns.' (251) Information as *thermodynamic depth* applied to 'special systems'

connotes a notion of *nomological* modality—vis-à-vis the laws of the particular special science in question whose ontology such systems comprise. Whereas *quantum information* (depending on the particular interpretation-e.g. n. 22 above) may connote logical modality (Duwell 2003), or nomological modality (Bub 2004), or even epistemic modality (Fuchs and Peres 2000).

I am in accord with Hawley's (2010) criticisms: Ladyman and Ross (2007) exhibit an excessive confidence in their PNC and PPC as suitable for the task of articulating an OSR in the spirit of naturalism. In turn, they dismiss prematurely some of the tools available in analytical metaphysics, which they would do well to avail themselves in a manner which would only complement and strengthen their substantial claims. I suggest as well in closing that some of Ladyman and Ross's nuanced ontological claims referring to the special sciences lend themselves to further scrutiny in the analytic enterprise of meta-ontology, specifically in its notion of *quasi-possible objects:* 'For any kind of quasi-possible object, Fs, it holds that it if Fs are quasi-possible, there is some language/framework L where 'Fs exist' are true.' (Eklund 2006, 325) In this case, the framework L is the particular special science in question, with its objects Fs bound by L's scale-relative ontology. If I am right, this would suggest an even more nuanced analysis of nomological modality, indexed by frameworks *qua* special sciences.

4. Marc Lange's Natural Necessity

To further refine my above claims by way of a constructive case, I turn to M. Lange (2009). Lange's analysis is squarely situated in the tradition of analytic philosophy of science and metaphysics, nevertheless devoid of the 'neo-scholastic' constitutive ontological assumptions that Ladyman and Ross (2007) cite from some sources as evidence for dismissing much of

contemporary analytic metaphysics *tout court*.[23] In essence, Lange utilizes the tools of analytic metaphysics precisely in that fashion, i.e. as playing a regulative role, and his overall naturalistic stance[24] remains steadfastly apparent (2009, 55, italics added):

> [I]f we take seriously the possibility that our intuitions have been corrupted by our philosophy, then we must step back, reconsider our conclusions, and seek reflective equilibrium. *Naturally I have tried to craft an account of law that saves the phenomena I find most central to scientific practice.*

A natural concordance the above passage shares with Ladyman and Ross (2007) is evident already in their opening claims concerning their methodology of explanation as *understanding* as cited above (p 10-11).[25] To add: 'Roughly speaking, structural realism is the view that our best scientific theories describe the structure of reality, where [*contra* non-realism, this] is more than saving the phenomena, but [*contra* scientific realism] less than providing a true description of the natures of the [putative] unobservable entities that cause the phenomena.' (Ladyman and Ross 2007, 67).

Prior to my further discussion of this rapprochement with Ladyman and Lange, a key semantic distinction needs some clarification concerning how their respective metaphysical claims get interpreted: viz. as *de re* or as *de dicto*.[26] Whereas the entire treatment of nomological modality in Ladyman and Ross (2007) accords to a *de re* treatment—insofar as fundamental structural features of the world are cashed out via 'real patterns' (Dennett 1991) modified according to machinery of information theory, Lange adopts the opposite approach: Since laws are a species of subjunctive *facts*[27], the interpretation is through and through *de dicto*:

> I am concerned only with the modality of facts—that is, with *de dicto* modality, not with *de re* modality. Moreover, I am concerned only with modalities where all necessities are truths, i.e. where nothing impossible happens. I thereby set aside doxastic…deontic, and teleological modalities, since (for example) that all persons are legally obligated to obey the nation's laws does not entail that all do. (Lange 2009, n. 5, 207-208).

For reasons I will argue below, this type mismatch presents no serious obstacle, as Ladyman and Ross's *de re* claims concerning objective modal structure naturally evince 'one level up' a *de dicto* propositional structure by and through which Lange's account of natural laws can logically supervene.[28]

For instance, in their discussion on the foundations of quantum mechanics Ladyman and Ross (2007) mention that:

> [E]ven van Fraassen concedes that Bell's theorem reveals something about the modal structure of the world [insofar as]…some correlations [violating the Bell inequalities] between physical systems are brute and not explicable in terms of either a direct causal link or a common cause…we claim that the acceptance of such brute correlations…*entails a metaphysical commitment to the objective modal structure of the world*, because the correlations in question are probabilistic and hence modal and not merely occurrent. (2007, 186-187, italics added)

The italicized portion in the above signals the *de re* interpretation of the 'objective [nomological] structure of the world,' indeed a hallmark distinguishing feature of OSR. Without such an objectively modal base, any robust or meaningfully objective *de dicto* reading of the 'world's subjunctive facts' (the lawmakers for Lange[29]) would resemble a castle built in the air: Hence the

de dicto propositional structure of the world's subjunctive facts naturally supervenes on the 'world's objective [read: *de re*] modality' of OSR—thus the projects complement one another, rather than being incommensurate.

4.1 *Nomic Preservation and Sub-Nomic Stability*

To distinguish laws from accidents vis-à-vis sets of counterfactuals, Lange introduces the following two principles:

> **Nomic Preservation (NP):** For any subnomic[30] fact *m*: *m* is a law if and only if in any context[31], $p \mathrel{\square\!\!\rightarrow} m$ for any *p* that is logically consistent with all the *n*'s taken together, where it is a law that *n*. (2009, 25)

To avoid problems in triviality, circularity, and arbitrariness (to be discussed below) the above NP filtering condition is supplemented with *sub-nomic stability*.

> **Sub-Nomic Stability (SNS):** Any nonempty set Γ (deductively closed) is subnomically stable if and only if for each $m \in \Gamma$: $\sim (p \mathrel{\Diamond\!\!\rightarrow} \sim m)$, $\sim (q \mathrel{\Diamond\!\!\rightarrow} (p \mathrel{\Diamond\!\!\rightarrow} \sim m))$, $\sim (r \mathrel{\Diamond\!\!\rightarrow} (q \mathrel{\Diamond\!\!\rightarrow} (p \mathrel{\Diamond\!\!\rightarrow} \sim m)))$, …. for all *p*, *q*, *r*…. such that $\Gamma \cup \{p\}$ is logically consistent, $\Gamma \cup \{q\}$ is logically consistent, $\Gamma \cup \{r\}$ is logically consistent, … (2009, 29)

Analogous to the PPC and PNC (Primacy of Physics Constraint, Principle of Naturalistic Closure) acting as regulative and constitutive principles for a naturalized metaphysics (as I mention in pp. 8-9 above) likewise can the NP and SNS be so understood as regulative and constitutive principles distinguishing laws from accidents.

That NP is a reliable regulative filter has to with the fact that it 'accord[s] well with our routine scientific practice of using the natural laws to ascertain what would have happened under

various hypothetical circumstances.' (Lange 2009, 25) Using the natural laws to ascertain what would have happened is taken care of the consistency condition 'with all the (subnomic facts *n*)[32] taken together, such that 'it is a law that *n*.' For example[33], consider the claim *p*: 'The Earth (like Uranus) is tilted on its axis by an additional 90^{o},' (i.e. the polar axis lies on its present equatorial plane.) Neglecting causal conditions perturbing the Earth's orbit to evince such a pole shift, certainly *p* is logically consistent with all the known laws *n* of classical mechanics.[34] Moreover, all the laws of classical mechanics fix the context of relevance, as counterfactual conditionals are notoriously context-sensitive.[35] Now consider m_1: 'The Earth has seasons,' versus m_2: 'Angular momentum is conserved.' Clearly $p \mathrel{\square\!\!\rightarrow} m_1$ is false[36] while $p \mathrel{\square\!\!\rightarrow} m_2$ holds: i.e., the former is an accident, the latter is not.

However, as it stands NP is simultaneously too weak as well as too strong. The impredicative element of NP (i.e. the fact that lawhood is tested by invoking *all* laws modulo some context of relevance) presents a *circularity* issue: For instance, m_2 is clearly a law in the context of classical mechanics.[37] *Triviality* is also apparent insofar as the range of *p* belong to sets which (by definition) are consistent with the first-order laws (i.e. the laws governing subnomic facts), which in the case of an accident *m*, this range would include ~*m*, but in the case of *m* being a law, it would not.[38] Lawhood seems to be obtained on the cheap, which 'amount[s] to the laws stacking the deck in favor of themselves.' (2009, 26) Moreover, circularity and triviality suggest *arbitrariness* as well, as a result of this impredicativity: 'The concept of natural law appears in NP on both sides of the 'if and only if';…NP can portray the laws as special, in virtue of their invariance under this range of counterfactual suppositions, only if this particular range of counterfactual suppositions is itself special already.' (27)

The SNS condition hence acts as a *constitutive* means of distinguishing lawhood to compensate for the above weaknesses of NP—in spite of its virtue of representing the sorts of counterfactual reasoning typically engaged in scientific practice (whether in the case of the scientists' formulating thought experiments or otherwise). 'Roughly speaking, a set of sub-nomic truths is 'subnomically stable' if and only if whatever the conversational context, the set's members would all still have held under every subnomic counterfactual that is logically consistent with the set—even under however many such suppositions are nested.' (29) I.e., recall (from NP) the condition of lawhood $p \mathrel{\square\!\!\rightarrow} m$ for p consistent with all first order laws n. Subnomic stability should hold under recursive embedding: $q \mathrel{\square\!\!\rightarrow} (p \mathrel{\square\!\!\rightarrow} m)$, $r \mathrel{\square\!\!\rightarrow} (q \mathrel{\square\!\!\rightarrow} (p \mathrel{\square\!\!\rightarrow} m))$, for $p, q, r, \ldots$ consistent with all first-order laws.[39]

From SNS, the set of first-order laws (laws governing sub-nomic facts) is trivially stable, which Lange labels this 'base' set as Λ. Moreover, (details omitted here[40]) *no* subnomically stable set containing (at least one) accident is sub-nomically stable: Its range swells under recursively nested counterfactuals to eventually contain *all* subnomic truths. Hence 'except perhaps the set of all subnomic truths.' (30) Thus Λ is the largest *non-maximal* set that is sub-nomically stable:

> [O]ur focus is on the proposal that laws differ from accidents in belonging to a sub-nomically stable set that does not contain every sub-nomic truth…Sub-nomic stability does not start by giving special privileges to laws. It is very egalitarian; it does not grant the laws the right to dictate to every set the range of counterfactual suppositions under which that set's invariance is to be tested. *Stability thus has the potential to be a genuinely special feature of the laws.* (30, italics added).

It is for this and other reasons offered by Lange that I refer to SNS as *constitutive* of lawhood.[41] In a relatively simple proof by reductio (details omitted here[42]), Lange demonstrates further that subnonically stable sets form a natural hierarchy of inclusion, i.e. for any two sub-nomically stable sets Σ and Γ, such that $t \in \Sigma$ and $t \notin \Gamma$ and $s \in \Gamma$ and $s \notin \Sigma$, then $\Gamma \subseteq \Sigma$ or $\Sigma \subseteq \Gamma$.

As an example of such a hierarchy of sub-nomically stable sets whose base consists of all the subnomic truths, 'there are…'strata' or 'levels' of natural law...metaphysical account[s] of what natural laws are should leave room for laws to come in multiple strata.' (41) In particular the first level above all subnomic truths would (Level-1) Λ, followed by the more-restrictive (Level-2) set of meta-laws $\Lambda^{(2)}$ (recall n. 37 above) consisting of, for example, in the context of relevance determined by physics, 'law(s) of the composition of forces, coordinate transformations, conservation laws…but not the force laws of the laws giving the physical characteristics of various kinds of particles.' (ibid.) The latter are, after all, first-order laws. Higher-level instances (e.g. $n \geq 3$) would consist of the set $\Lambda^{(n)}$ containing all 'broadly logical truths'[43] which are sub-nomic truths. Moreover, note that as evidenced by their logical strength (robustness under ranges of counterfactuals) and as rigorously proved in the general case of sub-nomically stable sets: $\Lambda^{(3)} \subset \Lambda^{(2)} \subset \Lambda \subset \{\text{subnomic truths}\}$.[44]

4.2 *The Varieties of Natural Necessity*

From the previous construction involving NP and SNS, Lange (2009), p 45-89) establishes a natural bijection with a hierarchy of nomological modalities of varying strengths, i.e. a hierarchy of natural necessity. For instance, the dual to NP is Lange's Modality Principle (MP):

> **Modality Principle (MP):** In any context, the subnomic fact *q* is necessary if and only if ~(*p* ◊→ ~*q*) for any *p* that is logically consistent with all the *n*'s taken together, such that □*n* (it is necessary that *n*). (74)

Dual to the SNS, MP can be extended to include nested counterfactuals in any context, provided 'the variety of necessity is genuine.' (74) (Note that 'genuine necessity' is distinguished from 'relative necessities,' insofar as the latter can arise in ordinary conversational contexts in which the necessity is bound by the conversationally relevant facts.[45]) Hence the isomorphism is demonstrated:

> We have, at last, arrived at [the]…main thesis: for each variety of genuine necessity, the sub-nomic truths possessing it form a subnomically stable set—and for each sub-nomically stable set (except the set of all sub-nomic truths, if it be stable), *there is a variety of genuine necessity where the sub-nomic truths so necessary are exactly the set's members*. In short, for the sub-nomic truths, there is a correspondence between the varieties of genuine necessity and the non-maximal sets possessing sub-nomic stability. (2009, 75, italics added)

Thus SNS along with MP evinces a natural hierarchy of necessity, or a systematic means of organizing modality in such a manner that extends and systematizes the claims of Ladyman and Ross's (2007) ITSR (information-theoretic structural realism) *qua* the 'rainforest realism' (RR) by which they derive their modal claims in the case of the special sciences. Adopting such tools from analytic metaphysics is not a mere exercise in window-dressing, but as I shall show in the final section, the machinery introduced by Lange goes a long way to 'clear the underbrush' in

this 'rainforest' by evincing a natural hierarchy of species of modality, faithful to scientific practice and to naturalistic metaphysics at large.

5. Conclusion: Implications for ITSR and Rainforest Realism—Clearing Some Underbrush

As discussed briefly in Section 3. above, information *qua* 'real patterns' (Dennett 1991) in its multiple senses (e.g. logical, thermodynamic, and 'quantum'[46]) constitutes Ladyman and Ross's (2007) OSR, by shouldering the primary metaphysical burden for characterizing PPC and PNC-compatible ontologies utilized by fundamental physics or by the special sciences:

> That there is such a distinction between real patterns and mere patterns (OSR), and how it is to be drawn…and that nothing else about existence in general should be said (PNC), is the content of the metaphysical theory defended in this book…The main ontological implication of OSR is that reality is not a sum of concrete particulars. Rather, individual objects, events, and properties are devices used by observers…to keep cognitive books on what science finds to be sufficiently stable to be worth measuring over time, viz. some but not other patterns…What OSR denies is that real patterns resolve 'at bottom' into self-subsistent individuals…we must put the 'at bottom' inside scare-quotes, because we find the levels metaphor misleading. *The single most important idea we are promoting in this book is that to take the conventional philosophical model of an individual as being equivalent to the model of an existent mistakes practical convenience for metaphysical generalization.* (Ladyman and Ross 2007, 228-9)

In their particular sections (4.4-4.5 2007, 220-238) the above metaphysical insight is backed up by a thoroughly technical exposition concerning how (scale relative) ontologies can emerge, viz.

'real patterns worth measuring over time' in such a mode and manner as to become individuated in terms of objects, events, properties, processes—ontological distinctions having *au fond* 'practical convenience' relative to a particular science (whether fundamental physics or special), but no 'fundamental' metaphysical import. I omit from my discussion the technical details here—save for mentioning in passing that a necessarily operative methodological notion rests on *projectibility*[47]—which is how the authors justify 'ontological implication of their [viz. such "devices used by observers"] without commitment to general reductionism or even supervenience.' (2007, 223).

One may ask, however, given the above considerations in section 4. above: is the 'rainforest' really *that* 'dense'? More to the point, accepting the underlying metaphysical claims being made here, i.e. that there *is* a means to consistently (within the constraints of PNC and PPC) 'locate' a species of 'vegetation' (analogous to a particular ontological domain in question for a particular science) by virtue of such information-theoretic considerations discussed in this section; nevertheless, as I indicated elsewhere, borrowing selectively certain tools and concepts from analytic philosophy may go a long way to refine and render more nuanced certain important modal distinctions that, as I have argued in the previous sections above, Ladyman and Ross (2007) have glossed over. In particular, what I suggest here in this concluding passage is a means to "cultivate" this rainforest using Lange's (2009) hierarchy of nomic necessity. Ladyman and Ross proclaim that nomological modality is given by fundamental physics, and that is the only genus of modality suitable for a metaphysics naturalized:

> *From the point of view of those engaged in special science activity, fundamental physics gives the modal structure of the world.* For philosophers who insist that talk of 'higher

> and lower orders of necessity just makes a nonsense of the idea of necessity altogether, the italicized claim operationalizes what we mean by such talk. (2007, 288)

I hope I have demonstrated herein by way of constructive counterexample that 'higher and lower orders of necessity' is by no means nonsense whatsoever, and furthermore such talk can be reconciled in a manner consistent with Ladyman and Ross's claims. More to the point: injecting some of Lange's (2009) notions into the authors' project of a metaphysics suitably naturalized (yet nevertheless supporting the framework of OSR suggesting a unified picture of science) can only render that picture more systematically complete, within a given domain of interest as demarcated by the particular science in question—whether fundamental physics or otherwise.

Acknowledgments

I thank Dr. John Bickle, (Chair, Department of Philosophy and Religion, Mississippi State University) for providing much valuable feedback in consultation during various stages of the formulation of this paper, and future re-formulations thereof.

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[1] As expressed by the criticism of leading non-realists like B. van Fraassen (1980-2008). Following (Ladyman 1998-2009) I use their term 'non-realism' to refer to the complement of scientific realism. Indeed, van Fraasen's empiricism is best characterized as such (as opposed to *anti*-realism) because of his ontological agnosticism and methodological neutrality.

[2] *Some*, but not *all*: van Fraassen 'argues that epistemology ought to be indexical and anthropocentric, and that the distinction between observable and unobservable…[has no] direct ontological significance, but rather epistemological significance.' (Ladyman and Ross 2007, p. 97)

[3] Others include Johannes Kepler, Isaac Newton, Henri Poincare, Bertrand Russell, Ladyman (2009).

[4] Namely, that Russell's (1911) ESR collapses to a non-realist phenomenalism.

[5] Latter-day adherents of the syntactic tradition are aware of the oversimplification at work here (many rudimentary theories in science contain mixed terms—the observation/theory distinction can be methodologically context-sensitive in a number of ways). Nevertheless, they claim that *in principle* a theory can be so analyzed. 'Toy examples' come to mind—e.g., o_1: 'velocity of ball', o_2: 'mass of ball', t_1: 'kinetic energy of ball.' Yet, even here, structuralists like (Sneed 1971) object: the observation/theory distinction is relative according to the *set-theoretic predicates* which formalizes the theory (i.e. , the θ-terms).

[6] These seven are not mutually disjoint.

[7]Benaceraff (1965) also advocates such a position.

[8] Ladyman (2009, 9) cites Mertz's (1996) 'network instance realism' as an eschewing of 'the tyranny of the monadic' as such an example thereof.

[9] An example of this position (jointly entailed by **OSR-3** and **OSR-4)** is quantum holism.

[10] In the phenomenological traditions, (macroscopic) objects are seen as heuristic devices by which agents can use to construct appropriate representations of the world and navigate therein. '[C]ognitive science may show that we are not able to think about certain domains without hypostasizing individuals as the bearers of structure.' (15)

[11] Critics are quick to issue their rebuttals, which I will discuss further in the sections below.

[12] Including Quantum Gravity (167-175) and the Everett-Saunders-Wallace interpretation (175-183).

[13] While OSR shares many methodological, epistemic, and ontic points in common with Bas van Fraassen's empiricism, ('constructive' (1980) or 'structural' (2006-7)) the central issue separating them is *objective modality*. 'van Fraassen…comes very close to our view. *The only difference between us is that we understand the relations in question to be nomological or more broadly modal, whereas he understands them to be extensional occurrent regularities*. ..[S]ome scientific realists of a Humean inclination…argue that van Fraassen is right about this latter point. We…argue that the marriage of scientific realism and Humeanism about modality is an unhappy one.' (Ladyman and Ross, 2007, 79, italics added)

[14] Ladyman (2009), Ladyman and Ross (2007) also examine objections to OSR—in particular Psillos's (2001, 2006) claim that since the dawn of 17th century modernism, substantival metaphysics was removed: so there may be no principled way of distinguishing a theory's empirical content from its structural content. The authors' skeptical rejoinder (2007, 157):

> Consider the claim that…forms, substances, and the likes was overthrown by the scientific revolution. How was the 'nature' of atoms understood? Atoms were understood as individuals. Boltzmann incorporated such an understanding of the nature of atoms in terms of their individuality into…his mechanics…the…discussion of individuality with respect to entities in physics, and the metaphysics of relations makes it clear that standard scientific realism has been saddled with traditional metaphysics.

[15] To wit: Individual substances (whether 'matter' or 'infostuff') comprising a compositional hierarchy putatively characterizing the world is a 'forlorn' activity, the authors submit:

> When it comes to debates about the nature of matter in contemporary metaphysics it tends to be assumed that…: either there are atoms in the sense of partless particles, or there is 'gunk' [and by extension, 'infostuff'] in the sense of…infinitely divisible matter. *This debate is essentially being conducted in the same terms as it was by the pre-Socratic philosophers…atomists were represented by Democritus and …'gunkists' by Anaxagoras…*It is preposterous that in spite of the developments in the scientific understanding of matter that have occurred since then, contemporary metaphysicians blithely continue to suppose that the dichotomy between atoms and gunk remains relevant, and can be addressed a priori. *Precisely what physics has taught us is that matter in the sense of extended stuff…has no counterpart in fundamental ontology.* (20, italics added)

[16] Reasonably precise criteria are posited to disambiguate and bound the vagueness of notions like 'scientific hypothesis'. (38)

[17] '[O]ur verificationism, unlike that of the logical positivists, is not a claim about meaning. The statement 'The Big Bang was caused by Elvis' is perfectly meaningful in all reasonable senses…we call the statement 'pointless'…it can make no contribution to objective inquiry.' (30)

[18] See Szabo-Gendler and Hawthorne (2002).

[19] In particular, Chalmers (2002) examines in detail, using the tools of two-dimensional semantics, metaphysical possibility vis-à-vis epistemic possibility (conceivability).

[20] As they accuse Dennett of 'waffl[ing] inconsistently between scale relativity of ontology and of epistemology.' (200)

[21] 'Let us operationalize the concept of a special science…a science is special iff it aims at generalization such that measurements taken only from a restricted area of the universe, and/or at restricted scales are potential sources of confirmation and/or falsification of those generalizations.' (195) Moreover 'since special sciences *do* seem generally to be about kinds of things and their causal powers…their metaphysical status [would be] mysterious' were it not for an attempt to characterize them in term of real patterns. (193)

[22] Three different positions claim that quantum information: a.) is a new physical entity Bub (2004), b.) is classical information stored in quantum systems Duwell (2003), c.) is just a subjective measure of degrees of belief Fuchs and Peres (2000). (184)

[23] As I briefly mentioned above, the responses by Hawley (2010) and Dorr (2010) certainly do well to call the reader's attention to this hasty generalization. However, to clarify, when it comes to the sin of ontological overreach committed by *some* in the field, Ladyman and Ross's (2007, 20) complaints concerning the atomists and 'gunkists' (recall n. 15 above) seem well-justified in that particular case. In essence, in the above passage and elsewhere the authors echo and extend van Fraassen's concerns of the 'inflationary metaphysics' in standard scientific realism (1980, 73), whose claims indeed are frequently addressed (66-130). However, while van Fraassen (1980-2002) targets scientific realism in a manner in which he adopts (in method) much of the standard tools of analytic metaphysics (e.g. set theory, modal logic, etc.), Ladyman and Ross's (2007) criticisms are broad enough in scope to echo their suspicion of such very methods to begin with:

> [Analytic] metaphysicians usually…use logic and set theory to formulate their theories. From our perspective this does not confer any extra epistemic status on their activity, but it may bamboozle the outsider or the student into supposing that the activity has much in common with mathematics and science. (2007, n.14, 14)

And even more tendentiously:

> We see no point in mincing words: it seems to us to be just ridiculous when philosophers look up from their desks and tell us while sitting there and concentrating they've discovered (usually all by themselves) facts about the nature of the world that compete with the fruits of ingenious experimentation conducted under

> competitive pressure and organized by complex institutional processes. The individual philosophers are not crazy; but quirks in the history and structure of the modern academy have encouraged crazy activity and hidden its absurdity. (2007, 57)

As I aim to show in this section, certainly Lange's project does not presume to 'compete' with the claims of fundamental or applied physics—only to systematically characterize such activity in the context of his analyses of nomological modality in the context of '[a] philosophical proposal [which] should be fruitful…by having welcome consequences that were not expressly built into it, yet follow…in a natural way.' (2009, 91)

[24] I adopt van Fraassen's (2002) notion of 'stance' in contrast to 'doctrine'. Borrowing from Husserl, a stance is 'an orientation or attitude towards the world.' (Ladyman and Ross 2007, 99). Whereas a doctrine is a body of beliefs by which one assents to certain claims associated with them as being literally true. Because an empiricist's or naturalist's body of beliefs is always subject to open-ended revision in the face of new evidence, van Fraassen argues that empiricism can never be affirmed as doctrine, lest one runs the risk of practicing philosophy in bad faith. 'A philosophical position can consist in…other than a belief [e.g., an instance of a doctrine] in what the world is like…A philosophical position can consist in a stance (attitude, commitment, approach…possibly including some propositional attitudes…as well)…[A] stance…cannot be simply equated with having beliefs or making assertions about what there is.' (2002, p 47-48). The Husserlian (really Kantian-transcendental) aspect of the notion of stance is perhaps more strongly articulated by (MacKinnon 1972, 67): 'If one accepts [some] systems of knowledge...as...relatively adequate expression[s], then one might ask what must the world be like if it can be known in the we do in fact [seem] to know it? This approach...is inadequate unless one considers not only the expression of knowledge through systems, but also the dynamics of knowing.' A stance, as I understand it, would do just that—i.e., cast the light of understanding on the 'dynamics of knowing.' In any case, I bring up this methodological and epistemological distinction in passing here, to illustrate how naturalism (broadly conceived) can be approached in terms of a doctrine or as a stance—For instance, van Fraassen (1980) characterizes scientific realism as a stance concerning the primary *aims* of science.

[25] To recall, an approach they claim which follows a methodological tradition evident in Sellars (1962) and Kitcher (1989) among others: '[W]e are interested here in a sense of 'understanding'…better characterized by the term 'explanation'…[In contrast] a given metaphysic's achievement of domestication furnishes no evidence at all that the metaphysics in question is true, and thus no reason for believing that it explains anything.'(1-2)

[26] The *de re* / *de dicto* distinction can be characterized in terms of a scope ambiguity with respect to any modal operator Ξ. *Ab initio*, at any rate, such a distinction can be read in terms of a narrow or broad scope interpretation for any modal operator Ξ applied in any modal statement $\wp$ involving the binding of its variables under Ξ. Consider, for example, the statement:

> $\wp$: 'It's possible a (at least one) woman will win seat(s) in the upcoming election.'

In (first-order) modal logic, $\wp$ can take the form: $\exists x$: ◊ (*Wx* & *Sx*), where *W* and *S* stand for predicates 'woman,' and 'will win seat(s) in the upcoming election.' The above first-order formulation corresponds to a narrow interpretation of the scope of ◊ (*de re*), which would make $\wp$ equivalent to the claim that, loosely speaking, 'there is at least one woman to whom it is attributable that (she/they) may win seats in the upcoming election. As the variable *x* is bound by the quantifier ∃ lying outside the scope of ◊, the sentence's information content is directed primarily towards the *object* (in this case, one (or more) woma(/en)), hence *de re*. On the other hand, a *de dicto* reading of $\wp$ above would be equivalent to the claim: ''At least one woman will win seat(s) in the upcoming election' *is a possibility*.' In other words, ◊ is attributed to the whole claim, so can therefore be exchanged with the existential quantifier to yield the form: ◊[$\exists x$:(*Wx*&*Sx*)]. The sentence's information content is directed primarily towards a *statement* ('At least one woman…'), hence *de dicto*.

[27] Insofar as facts of course correspond to an abstract, propositional structure. Moreover 'the universe's state at a given moment cannot be purged of irreducibly subjunctive facts,' (2009, xiv) insofar as, for example, instantaneous rates of change lend themselves to a naturally subjunctive interpretation: '[A] quantity's instantaneous rate of change at time *t* traditionally plays various causal and explanatory roles…[and] [t]he best way to account for the causal and explanatory roles…is to interpret the rate in terms of some irreducibly *subjunctive* fact.' (ibid) To take

the homely example of velocity, for instance, according to Lange naturally connotes that the case '*were* the body (existing at *t*) to remain in existence after *t*, the body's trajectory *would* have a time-derivative at *t* equal to v' (ibid.) Elsewhere Lange argues that subjunctive facts are what underwrite *natural necessity*—i.e. the distinctive kinds of nomological modality providing the structure of sets of laws (135-189). 'If such [subjunctive] facts must be countenanced as anyway, parsimony urges us to put them to work as lawmakers.' (xiv)

[28] So long as, to recall Section II above, one doesn't adopt an ESR reading of such facts. Indeed, such a latter reading is automatically preempted in Lange, as all the counterfactuals utilized by Lange from the get-go, 'involve aletheic modalities, not…epistemic modalit[ies].' (2009, n. 24, 196)

[29] See n. 27 above.

[30] I.e. propositions without embedded 'it is a law that…' operators. I.e., 'energy is conserved' is a subnomic fact, whereas 'It is a law that energy is conserved' is not.

[31] This is Lange's shorthand for counterfactual conditionals: $p \mathrel{\square\!\!\rightarrow} m$ should be read as: '*Had p* been the case, then *m would have* been the case.' Elsewhere, Lange connects such counterfactual conditionals with subjunctive 'might have' statements: $p \mathrel{\Diamond\!\!\rightarrow} q$ is shorthand for '*Had p* been the case, then *m might have* been the case.' In particular, see n. 24, 195-195: The following entailment is demonstrated $\sim (p \mathrel{\Diamond\!\!\rightarrow} \sim q) \Rightarrow p \mathrel{\square\!\!\rightarrow} q$. However, Lange argues against the converse entailment, and thus denies an equivalence between 'not-might-not have' with 'would have' (as opposed to the ordinary, i.e. non-counterfactual, case in modal logic, i.e. $\sim\Diamond\sim \equiv \square$). The principal reason why Lange denies the converse entailment has to do the with the Modality Principle (MP) discussed in 63-71, of which I will discuss in more detail below.

[32] See n. 30, 31 above.

[33] Combining several relatively intuitive examples that Lange discusses throughout certain particular sections (viz. §§I.6-I.9, 25-42)

[34] The very existence of cases like Uranus of course provide the empirical support for such a consistency claim.

[35] So irrelevant claims to test for lawhood in this example about the Earth's axis may include propositions from fields in fundamental physics like quantum gravity, involving spatial separations at the Planck scale ($\sim 10^{-35}$ m), or propositions from deontic modal contexts, etc. 'My purpose in offering this argument [for NP] is…to explain why it is not unprincipled to acknowledge context's tremendous influence on what is preserved under a given counterfactual supposition, and yet to insist that in any context, the laws are preserved under any sub-nomic supposition logically consistent with them.' (n. 34, 206)

[36] I.e. from n. 31 above: *Had p* been the case, then m_1 *would* have held.

[37] Albeit, like conservation of energy, a *meta-law* (Lange 2009, 19) or a law governing other laws (not necessarily deterministically, to accommodate the statistical cases), the latter governing subnomic facts. For example, the latter case would be Newton's second law applied to rotational systems, i.e. $\Sigma \tau_{CM} = {}^{dL}/_{dt}$ i.e. the sum of all the torques experienced on a rigid body's center of mass is equal to its time rate of change of its angular momentum, in which $L \propto I\omega$ (i.e. a rigid body's angular momentum is proportional to the product of its rotational inertia and its angular velocity about its rotational axis—*pace* the Parallel Axis Theorem it is presupposed to go through the body's center of mass.) Now such first-order laws could have been expressed by different formulae, without affecting the conservation principles which are metalaws. In addition, meta-metalaws (laws governing metalaws) would include examples symmetries like Einstein's Equivalence Principles in general relativity or GR: any frame of reference undergoing uniform acceleration is locally equivalent to a frame of reference in free fall in a gravitational field. Laws governing meta-metalaws (meta-meta-metalaws) would include super-symmetry: For instance a boson (a particle consisting of integer spin number) is associated with fermion (a particle consisting of half-integer spin number) in a superpartner, i.e. a particle-pair whose constituents otherwise share the internal quantum number and

mass. Though no superpartners have yet to be observed, supersymmetry evinces some attractive mathematical results in Gauge theory, e.g. as when affixed as a local symmetry, Einstein's GR is derived as a result.

[38] Recall the example: Certainly $\sim m_1$, i.e. the Earth would *not* have seasons, is consistent with all the laws of classical mechanics, etc., in the above example. But $\sim m_2$ (conservation of angular momentum is violated in this case) clearly isn't.

[39] Recall n. 31 above: The recursive *would* counterfactual conditionals entail *not-might-not have…* ones, as exhibited in SNS's formulation.

[40] Lange provides a proof in § I.8 (32-36).

[41] Nevertheless in this discussion Lange is careful to point out that '[i]n this chapter, I am concerned only with *identifying* the special relation between laws and counterfactuals, not with figuring out *why* this relation holds.' (31)

[42] See § I.9, 37-42.

[43] In the illustration Lange sets $n = 3$ as 'broadly logical' necessities (i.e. truths, since the context is aletheic, recall n. 28 above) these would encompass: i.) *narrowly* logical necessities (e. g. either all Fs are Gs or some Fs are not Gs), ii.) Conceptual necessities (all brother are male), iii.) Mathematical necessities (there is no largest prime number), iv.) Moral necessity, i.e. 'moral laws [which are] theorems of the correct moral theory…[hence] possess[ing] moral necessity.' (n. 4, 207) To wit, 'broadly logical' case iv.) contrasts with Lange's admission of setting aside doxastic modalities (as he mentions in the next item) yet he does well to mention this species of modality in passing, as part of the genus of 'broadly logical' as just listing extensions of the latter term. I qualify his claim here nevertheless with the inequality, since Level-3 also encompasses meta-metalaws (recall n. 37) which may involve exotic instances like supersymmetry. Whether or not supersymmetry is just an instance of iii.) is at best a controversial case—certainly despite the null results from super-colliders many high energy physicists are still on a quest to discover superpairs. If so, one may balk at the presumption that all meta-metalaws are broadly logical necessities, hence suggesting that broadly logical necessities are at least Level-4—or else balk at the claim that super-symmetry is a bona fide Level 3 meta-metalaw (some physicists argue in favor of abandoning it). One might add in addition that since Lange focuses on aletheic and not epistemic modality (recall n. 27) the issue of aprioricity (are all broadly logical necessities a priori?) is not relevant.

[44] A few examples here may be in order: strenuously obvious cases would include any contingent fact (Level – 0) p_0 like 'Bob missed the bus' once the indexical and truth-conditions (or 'character' and 'content', Kaplan 1989) are in place. Certainly $p_0 \in$ {subnomic truths}, but is not a member of any level n ($n \geq 1$) subnomically stable set. The proposition p_1: 'Two charged bodies at rest experience a force proportional to the product of their charges and inversely proportional to the square of their distance measured by the spatial separation of the bodies' centers of mass, in the direction along a line of action connecting their mass centers,' i.e. Coulomb's Law, is a case in which $p_1 \in \Lambda$ and since Λ is the largest non-maximal subonically stable set, then (as confirmed by intuition in this case) p_1 is a subnomic truth or more precisely, noting the discussion above, $\Lambda \subset$ {subnomic facts}, as proved by Lange (§ I.9: 37-42) that subnomically stable sets form a *chain*, i.e. are *totally ordered* via set the inclusion relation $\subseteq$. Note that $\subseteq$ is a partial ordering relation (i.e. is *reflexive*: for any set S: $S \subseteq S$, *anti-symmetric*: For any two sets S, T: $S \subseteq T$ and $T \subseteq S$ if and only if S = T, and *transitive*: For any sets R, S, T: if $R \subseteq S$ and $S \subseteq T$, then $R \subseteq T$). Moreover, note that Lange's proof rendering subnomic stability a total ordering is the demonstration that any two subnomically stable sets are *comparable*: i.e., given (subnomically stable) Σ, Γ: then either $\Sigma \subseteq \Gamma$ or $\Gamma \subseteq \Sigma$. Thus, giving these précising claims, note further that $p_1 \in \Lambda - \Lambda^{(2)} = \{t | \ t \in \Lambda \ \& \ t \notin \Lambda^{(2)}\}$ which is non-empty, i.e. p_1 is *exclusively* a law governing a subnomic fact. (Recall also (n. 30 above) that it p_1's facticity is formally secured by virtue of the absence of the 'It is a law that…' operator). Hence, an *exclusively* Level-2 subnomic fact would be p_2: 'Energy is conserved.' i.e. $p_2 \in \Lambda^{(2)}$ and $p_2 \notin \Lambda^{(3)}$ or belonging to the non-empty set $\Lambda^{(2)} - \Lambda^{(3)}$. An exclusively Level-3 (or higher?—Recall n. 43 above) would be any broadly logical claim p_3—whether mathematical, narrowly logical, or otherwise.

[45] One might privilege such relative necessities with (conversationally relevant) modifiers like 'It was unavoidable that...' Consider for instance the example discussed by Lange involving Luciano Pavarotti having laryngitis as

explaining why his failure to sing for the evening of his scheduled performance was an unavoidable fact. That this necessity is relative is clear from the conversational context: 'What suffices in the audience's context to make Pavarotti's failure to sing 'unavoidable' does not make it 'unavoidable' in the physician's context.' (2009, 61) Precisely stated: 'The explanatory significance of a merely conversational modality is just as temporary as the context that brings it into salience. [Whereas] [m]athematical and natural necessity…are explanatorily potent in any context.' (61-62) To be sure, however, this is just a first-pass means of setting apart 'genuine necessity' since *au fond* 'if all necessities are merely relative to some or another set of conversationally relevant facts, then it seems arbitrary for us to regard *p*'s natural necessity as really making *p* inevitable but *q*'s 'necessary' relative to some other class of facts…' In that regard, Lange's MP acts as the regulative 'filter' (as NP filters out lawhood) for genuine necessity: MP's 'holding in both directions generalizes NP to all flavors of necessity…if the laws are exactly the natural necessities, and natural necessity must qualify as a variety of necessity in every context, then NP follows from MP's holding in both directions.' (66) Again, 'when a merely relative modality divides the facts into the necessities and the contingencies, either MP fails or the division turns out to be between the facts that we care about and those that we do not.' (70) In the latter case, recall n. 31 above concerning the context of relevance. This can be stated negatively as 'a genuine modality upholds MP without every relevant fact having to be necessary.' (71) As Lange further illustrates, according to natural laws, a box of prunes he would be holding could not be shipped at superluminal speeds, for instance, and every relevant fact in this context need not be necessary for the claim to hold true: 'Had the price [of prunes] been different or the weather in plum-growing regions been different, then the laws would still have held…MP exerts no pressure to expand the range of natural necessities to include facts about the price or the weather.' (ibid.)

[46] Recall n. 22 above, i.e. the associated ambiguity of its interpretation, at least by present-day schools of thought in the physics and philosophy of physics communities.

[47] The notion is introduced by way of 'locator functions', which itself according to Ladyman and Ross is evidential of objective modality, insofar as '[o]bjective modalities in the material mode are represented by logical and mathematical modalities in the formal mode.' (2007, 119) In particular, as 'particular theoretical structures in the formal mode…represent particular intensional/modal relations among measurement results as "phenomena", so long as it is understood that phenomena are not sense-data in the positivists' sense,' (ibid.) so the ostensive operation of picking out a real pattern is (in the 'formal mode') represented by the locator function, i.e. the 'act of "tagging" against an established address system.' (121). The dimensionality of such a locator function is characterized by the maximum number of parameters necessary to make the distinctions (of the real pattern in question being thus located) precise enough in the context of the particular investigation. (222) Projectibility is then leant a more precise characterization in the formal mode, 'as requiring a computation of the value of one or more measurable properties…in terms of dimensionality *D* [of the locator function], given input of a measurement taken by a physical computer M…[c]omputation [however] is necessary but not sufficient for projection.' (223) In this regard, '[p]rojectibility is a modal notion…just a better-than-chance estimability by a physically possible computer,' where '[e]stimability should be understood as estimability in the actual world that science aims to describe, not as estimability in some class of possible worlds.' (224) Real patterns are then characterized via projectibility in the sense that the following necessary and sufficient conditions hold: (i) the pattern 'is projectible in at least one physically possible perspective,' (226) and (ii.) such a pattern will encode information 'about at least one structure of events or entities…where that encoding is more efficient, in information-theoretic terms, than [the pattern's] bit-map encoding…' (226)