Taking Ontology Seriously

Quine's Thesis of Holism and Underdetermination Applied to the Sciences in the Age of Technoscience

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Taking Ontology Seriously: Quine's Thesis of Holism and Underdetermination Applied to Visuality in the Sciences in the Age of Technoscience

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Abstract

The visualization in the contemporary sciences has renewed the relevance of a certain aspect of post-positivistic epistemology, namely the relation between fact and representation. The visual computational turn has altered the working conditions for various sciences. If theory in classic science was regarded as framing the facts, now the pictorial facts define the representation. The picture emerges seemingly regardless of any theoretical approach. Rather than pure theoretical competence, the interpretative experience is the preferred professional virtue.

This paper addresses the question what conceptual resources post-positivistic analytic philosophy offers for an analysis of epistemic realism in visualized science. A suggestion is that W. V. O. Quine's thesis about the holism and underdetermination of theory might be helpful devices for analyzing the ontological aspects of scientific computational generated pictures. Quine's holism aims to hold for all branches of sciences including mathematics (W. V. Quine, 1992). Holism can be interpreted as the thesis that evidence rest on theories as wholes and not on individual parts of a theory. Hence, in general scientific pictures lack a secure empirical content taken in isolation from one another. But conjoined into series of pictures or corpus of pictures, the depictured phenomenon has an empirical content. Underdetermination can only obtain for complex theories, which are not empirically warranted. Taken together with the underdetermination thesis i.e. that observations alone do not determine theory; holism can be used for at the same time acknowledging a theory's fallibility and preserve a scientific realism (Bayer, 2007).

In his last versions of the underdetermination thesis Quine asserted that it was a confusion to suppose that we can stand aloof and recognize alternative ontologies as true (W. V. Quine, 1975). Given a certain ontology an object exists; given another referential coordinate system the object doesn't exist. Ontological questions can only be raised and answered in relation to the chosen referential system that applies meaning to the phenomena. We can only speak about what exists and not exists, relative to a certain ontological versions of reality. Different versions can be equally correct, though we can' t use the descriptions simultaneously. Infinite regress can be avoided, if we accept the criteria in use are rationally acceptable.

In molecular protein biology after the crystallization process is successfully done the measured density between electrons are modeled into pictures in order to grasp the where the atoms are sitting in the molecule (Brändén & Tooze, 2009).The next step is to apply another pictorial model, a structural model in order to find the specific shape of the protein molecule at display. During the visualization process the choices of colors work as explorative devices in order to find to the best final model that matches density and structure. The pictures are efficient and necessary tools on the way to find out the protein structure in the molecules. A conclusion is that the visual representation aims at shaping and strengthening the ontological realism by combining two depictured aspects of the molecule, the density- and the structural models. The series of visual pictures illustrate that several preliminary satisfactory visualizations exist, not a

single one carries the full content. Some conclusions are 1) The visual representation has holistic connection to reality in the Quinean sense, though originally beyond our senses. 2) Scientific realism is still a valid position and hence the quest for objective truth within the chosen ontological system 3) Despite the pervasive computerization of scientific imaging, traditional concepts such as objectivity and realism are still valid connotations, however in new constellations. 4) Last, but not least, creating, practicing and analyzing scientific pictures require ontological competencies to serve the wanted epistemic goals.

Introduction

The topic of this paper is to explore what conceptual resources the analytic philosophy of science can provide for a workable epistemological framework for computational pictures. A general and widespread opinion is that the analytic philosophy of science has marginal relevance for contemporary science and technology studies (STS), even in the post-positivistic versions. The STS area would not agree the contemporary analytic philosophy of science have succeeded in developing new interpretative theoretical and methodological tools, distinct from the formal techniques represented by the twentieth century philosophy of science.

A pertinent question is then why turning to analytical philosophy of science to look for analytical tools? Firstly, the "the ontological turn" in STS has shown a renewed need to go beyond the material turn and "display the multiplicity of realities hidden … and seemingly undisputed signifiers… The purpose of researching ontology then, would not be to arrive at a better formulation of the reality of the world … but to interfere with the assumption of a singular, ordered world and to do so by re-specifying hefty metaphysical questions in mundane settings and in relation to apparently stabilized objects "(Woolgar& Lezaun 2013, p. 323.) The new focus in STS on ontology with curiosity for discover paths to failed or yet unseen realities is well in line post-analytic philosophy. Another shared belief is that science is our most valid and ultimate route to knowledge about the natural world.[1]

Secondly, analytical philosophy of science has a continued to focus on questions about truth, objectivity and scientific realism which still are central questions in the new visualization science techniques. For a decade back these questions might be considered as anachronistic and obsolete in the empirical materialistic focus in science studies. As the science studies has matured the questions about metaphysics and ontology have return. The computer generated visual images are fundamental research tools in physics, biochemistry, biology to mention some areas. A

[1] Most philosophers of science tend also to hold the view that it exists an autonomous class of philosophical problems, esoteric for the sciences. In general the sciences tend not to reflect much on philosophical questions which is the business of the philosophy of science. GIVE EXAMPLES

look at the last decade of the awarded Nobel prizes in the sciences underlines the importance of visual technologies for mapping former hidden aspects of the natural world. Visualization techniques also plays an essential part in theory development. A claim is that the visual turn in the sciences have renewed the relevance of traditional epistemological and ontological perspectives; truth questions about the correspondence between the computer generated images and the natural world to which they refer. Analytic philosophy of science comprises an impressive body of concepts concerning the science relation to reality. A look at the contemporary history of philosophy of science reveals distinct treatises, not enclosed in formal and technical languages, that can provide the prevalent discussion about truth and authenticity in computer generated scientific visualizations with clarifying conceptual tools. The old prejudiced opinion that philosophy is a kind of super science has few if any adherents. The post-positivistic philosopher W. van O. Quine theses about holism and under determination of theory, which I claim have a strong potential to provide a valid ontological framework for interpreting the ontological status in computational generated pictures.[2]

Several of his students further developed and radicalized Quine's heritage in very different ways. Among them Hilary Putnam and Richard Rorty are most known outside the philosophy departments.[3] Their influence might have led to a greater acceptance of a variety of approaches among analytic philosophes than for twenty years ago.[4]

In the contemporary world of modern science, populated by entities invisible for the human eye such as protons, neutrons and DNA molecules it has been questioned whether the conceptual division into representation and intervention of nature still are valid to do. The argument is that sectors in chemistry, biology and physics in working alliance with the mathematics and engineering exceed the interventionist track: they invent nature. The goal is "not to prove the existence of some particle … to establish the reality of some neutral currents, positrons, the omega boson, or the Higgs boson … these nanosicentists were not worried … that

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[2] W. van O. Quine presented his thesis about the indeterminacy of translation in *Word and Objects* 1960.

[3] One landmark was Richard Rorty's famous book *Philosophy and the Mirror of Nature* (Rorty, 1979). The idea of knowledge as a mental representative mirror of mind-external world was questioned with help of pragmatism, historicism and naturalism. *Reason, Truth and History* by Hilary Putnam is another of example of analytic philosophers opening up new paths to understand truth questions (Putnam, 1981).

[4] *Synthese,* the journal for epistemology, methodology and philosophy of science devoted an issue 2010 to the theme: "Making Philosophy of Science more Socially Relevant" and introduced a new abbreviation SRPOS (socially relevant philosophy of science) which proclaims a new orientation for a philosophy of science. See ("Engagement for progress: applied philosophy of science in context," 2010)

the nanotube existed when it did not or deceived into thinking that their image was true to nature when it wasn't (Daston & Galison, 2007, p. 393).

In the 1990s the concept "technoscience" was introduced as an adequate term for the new science, suggesting an epochal break with former modes of scientific knowledge production in late modern Western societies.[5] Technoscience represents a new knowledge hybrid which intertwines theoretical representation with technical intervention. In the former period, science aimed at exploring and understanding the fundamental laws and forces of nature, a tradition well known from the history of physics. The old distinction between theoretical science and applied technology visible in the institutional separation of science and engineering in the universities was assumed to become less valid. The motto from the Chicago exhibition 1933 "Science finds, industry applies, man conforms" was now bypassed by new constellations; the scientists are entrepreneurs commuting between the science community and the market (Rydell, 1993, pp. 98-99). The German philosopher Alfred Nordmann defines technoscience in the following way:

> In technoscientific research, the business of theoretical representation cannot be dissociated, even in principle from the material conditions of knowledge production and thus from the intervention that are required to make and stabilize the phenomena. In other words, technoscience knows only one way of gaining knowledge and that is by first making a new world (Nordmann 2006, p. 2).

The definition highlights the tension between theory and technological intervention. Simultaneously institutional transformations took place, from state- and university finanzied research to market and company driven research. Science has become "an essentially practical endeavor; it appears inextricably interwoven with technology and heavily intertwined with the economy, politics, the media and other realms of society"(Carrier & Nordmann, 2011, p. 1).

As an argument for the interventionist view, a description what is performed at the synchrotron facility MAX IV at Lund University can clarify; to use neutrons and photons to penetrate different materials, anything from plastics to proteins, in order to detect the arrangement of atoms and entities on the subatomic level and their minute displacements that can impact behavior and properties at the human scale. This description supports both the realist and anti-realist view, i.e. to suspend the truth questions and regard theories as mere instruments for calculation and prediction of observable or manipulated phenomena. For the practicing

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[5] Different labels are used to designate this change. In Europe "mode 2" research is the most popular, while in US the most popular terms are "entrepreneurial science, triple helix, post-normal science" and technoscience, the latter term seems to be in ascendant. See (Carrier & Nordmann, 2011, p. 2)

techno scientist, it is unnecessary to align oneself with either the anti- or the realist view, she can neglect both positions. The metaphysical and ontological questions are usually not of much interest. The valid question is "how does it work", not what exists out there.[6] However, regardless of the extension and existence of technoscience, a renewed philosophical concern for the technoscientific construction of reality is needed. Philosophy of science hasn't shown much theoretical interest for the new moods of science production, though it evokes a range of classical philosophical topics such as objectivity, truth, representation, perception, in short quite basic questions concerning the epistemology and ontology of the sciences. This paper aspires to give one example from the repertoire of philosophy of science and how it can be applied on new areas, specifically for interpreting visual practices. Visualizations abound in all forms of research and knowledge production; the pervasive computerization has triggered an immense visualization production which is a shared feature for almost all scientific areas.

Firstly, I discuss the analytical resources in W. van O. Quine's thesis about the holism and underdetermination of scientific theories as a possible general ontological framework for analyzing representational questions in scientific computational generated pictures. My claim is that Quines thesis offers conceptual resources to articulate some parts of the epistemological and ontological relations between the computational images and reality. Secondly, I give some examples of the function of visual representation in molecular protein biology. In molecular protein biology the visualizations are important research tools for both producing and communicating research results. The pictures illustrate the intervening strand in the contemporary techno sciences; they are not mere representations of a complex phenomenon, but explorative working tools constructed by mathematical computerized data, summarized into workable formulas, presented as visualisations, constructed by the engineers and delivered to researchers. A claim is that even if new computational technologies simultaneously intervene and invent nature, present facts in artful aesthetic designs, the truth questions have kept their immediacy.

Quine as a theoretical resource in post-war analytical philosophy of science for interpreting scientific visualization

> The totality of our so-called knowledge or beliefs, from the most casual matters of geography and history to the profoundest laws of atomic physics or even of pure mathematics and logic, is a man-made

[6] My claim is not that the interventionist view in order to depict reality is sidestepped; rather the different modes exist side by side. At the synchrotron MAX-III facility at Lund University neutrons and photons are used to penetrate different materials, anything from plastics and proteins to medicines and engineering materials.

fabric which impinges on experience only along the edges. Or, to change the figure, total science is like a field of force whose boundary conditions are experience (W. V. Quine, 1951, p. 40)

W. van O. Quine's philosophical oeuvre represents the characteristic traits of the post positivistic analytical philosophy of sciences; a theoretical revolt against logical positivism but kept within an orientation towards logic, mathematics, theoretical linguistics and viewing these subjects as closely allied for making philosophy into a science. According to Quine the progressive success of physics, chemistry and biology was due to their mathematical orientation. During his whole professional life Quine maintained that philosophy proper is linked to the natural sciences. In an interview 1993 he stated: "I see the philosophy as the handmaiden of the sciences and I have visions of its being increasingly useful in a practical way for the sciences as the old rather artificial barrier between philosophy and science are weakening ….Philosophy is tying up the loose ends of science" (W. V. O. Quine, Føllesdal, & Quine, 2008, pp. 35, 45). He emphasized repeatedly that the most rewarding aspect of philosophy is "clarification of the nature of the world, the nature of reality" (ibid. s. 30).[7] Philosophical and mathematical talents are closely linked.

For Quine, most of the humanities had little relevance for philosophy. His argument was that the humanities lacked scientific ambitions, and hence had no connection to philosophy of science (ibid. s. 34). Neither had philosophy of science any connection to politics or the social world. Applied or public engaged philosophy of science took little space in Quines philosophical universe. However, there is no doubt that Quine had a quite a great influences on the humanities in the early 1960s and 1970s. Quine's elucidation of the indeterminacy between language and the world, written from an ontological perceptive though aimed at the sciences, was highly relevant for the humanities as well (F. R. Ankersmit, 2005, p. 61).[8]

Hence, it looks less paradoxical that Quine inspired a second generation of analytic philosophers who consciously and systematically developed positions that questioned scientific realism, the fact-and-value dichotomy and the standard analytic definition of knowledge as justified true beliefs." Donald Davidson, Michael Dummet, John McDowell, Hilary Putnam, Richard Rorty and John Rawls are prominent names of this second generation that radically developed the earlier philosophy of science positions, represented by Quine.[9]

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[7] Quine shared the positivists belief that symbolic logic was the superior language for understanding science, a way to clarity and truth.

[8] References?

[9] A tradition that could explain the amazing intellectual vivacity within analytic philosophy is the US pragmatist tradition and William James' influence (Putnam, 1997). The European philosophy in general and Scandinavian philosophy in particular lacks a

A connection between Quine and the second generation was the interest in language and philosophical ontological problems. If the (only) access to reality is through language, the next concern is what this ontological relation looks like. Quine rejected any form of reductionism, i.e. that a single statement could be verified or confirmed by an empirical evidence. He proposes that the whole field of statements are interconnected in an ontological scheme and a necessity is to be present in the same language system.

> The very term 'thing' and 'exist' and 'real', after all, make no sense apart from human conceptualization. Asking after the thing in itself apart from human conceptualization, is like asking how long the Nile really is, apart from our parochial miles or kilometers (W. V. O. Quine et al., 2008, p. 416)

> Applied to abstract objects – number, say, or classes – this is not surprising. Take the class of past English monarchs. We might agree on its members, but might not your *class* of them and mine be different objects? Perhaps *membership* in your sense is *nonmembership* in mine, and then your class of past English monarchs is my class of everything else (Quine 1993).

Analytical philosophers (Davidson and Rorty) and poststructuralists (Derrida) ended up with the same solution; ontology could only be transferred through language, the available language determined our reality. Quine's philosophy invited and had the capacity to host a radical concern, that lately have been in the center for science studies, namely that the scientific practices perform the world and bring different worlds into beings. Quines position is far from the view that the epistemology is modelled on one single essential version of reality. The famous paper "On what there is" written 1951, was followed up by later works that went on examining ontological questions (W. V. O. Quine, 1951). The epistemology does not represent a static experienced world; our experience is a part of web of beliefs. Before we accept or revise a belief, a test take place on a psychological level, whether the belief fits into our web of connected beliefs, i.e. in our experience as a whole.[10] This holds not only for scientific practice; it is a general human feature for everyday life. All of our beliefs hold at any given time are linked in an interconnected web.

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pragmatic tradition and hence that interpretative tradition of Quine. However, according to Frank Ankersmit, they all kept the analytical rejection of historism.. Ankersmit asserts that Rorty rejected historicism and became trapped in linguistic transcendentalism, inspired by Donald Davidson. See (F. R. Ankersmit, 2005, p. 39ff).

[10] During the 1950s B.F. Skinner, the founder of American behaviourism, influenced Quine to develop his behavioral theory of language acquisition. That theory led Quine to further developing one of his most original theses, on "the indeterminacy of translation" (W. v. O. Quine, 1960).

The totality of our so-called knowledge or beliefs, from the most casual matters of geography and history to the profoundest laws of atomic physics or even of pure mathematics and logic, is a man-made fabric which impinges on experience only along the edges. Or, to change the figure, total science is like a field of force whose boundary conditions are experience. A conflict with experience at the periphery occasions readjustments in the interior of the field. Truth values have to be redistributed over some of our statements. Reëvaluation of some statements entails revaluation of others … But the total field is so underdetermined by its boundary conditions, experience, that there is much latitude of choice as to what statements to reevaluate in the light of any single contrary experience. No particular experiences are linked with any particular statements in the interior of the field, except indirectly through considerations of equilibrium affecting the field as a whole (W. V. O. Quine, 1951, p. 42f).

The philosophical focus on language evokes the question about the accuracy to apply its framework on scientific pictures. My short answer is that the ontological relativity that Quine successfully argued for, that there exists no God's bird eye view on reality is highly pertinent for visuality in the sciences (W. V. O. Quine, 1969). The ontological uncertainty in understanding linguistic utterances and scientific visualizations have strong similarities. Both can be regarded as utterance that can't be verified or by one single statement or detail in the picture. The truth value depends on the taken ontological position. Similar indeterminacies exist for computational pictures as for linguistic utterances. The utterance refers to an object in the world, but the reference encounters similar difficulties to those between an object and the representational picture. A computational picture can depict a nanoworld, only available through computational facilities.[11] The physical facts' transformation to a ready picture is opaque, done by computational techniques; the composed representation is not equal to its factual basis.[12]

An important feature of Quine's oeuvre was that it opened up for a discourse that the logical positivists had banished: ontology. From his debut with the article "Two dogmas of empiricism" (1951) to his last monography *The Pursuit of Truth* he altered the approach of how to handle the epistemological concerns that was a salient feature for earlier generation of analytic philosophers, hence his status as the founder of the post-analytic philosophy (W. V. Quine, 1992).[13] When Quine widened the scope of epistemology to include ontology, he inspired to a general philosophical revision of theories of knowledge that had repercussions also outside the

[11] The concept "natural world" is less accurate, as many of the bio-scientific pictures are hypothesis about what can exist, not what actually exist. This holds also in nanotechnology where new materials are created, which don't exist in nature.

[12] For an overview of STS about visualization in the sciences see (Carusi, Hoel, Webmoor, & Woolgar, 2015).

[13] For an overview of Quines philosophy, see (Gibson, 2004).

philosophical departments. Imre Lakatos and Paul Feyerabend were inspired to question methodologies as a secure way to scientific success. (Feyerabend, 1975; Lakatos & Musgrave, 1970). The success of a theory or research program might be a function of "the differences in talent, creativity, resolve, and resources of those who advocate them."[14] Another version of these thoughts was elaborated by Thomas Kuhn, not stressing creativity but that a dogmatic science community fostered to think along with the ruling paradigm.[15] Evidence and logic mattered, but also external factors – non-logical considerations played a decisive role in science production.

Today science and technology studies (STS) is the most ardent offspring of the radical change that Quine initiated for more than fifty years. Post-analytic philosophy and science studies share the view that the holist underdetermination, *path* Quine, shows that evidences or facts alone cannot verify the theory. The disagreement is about which factors are decisive for accepting a theory.[16] In accordance with their intellectual affiliation, sociologist tend to emphasize power relations, science historians underline historical factors, and gender theorists give attention to gender relations.[17] One evident strength of STS - in contrast to philosophy of science- is that the ontological or epistemological theories are applied to understand and analyze how the interconnections between theory and practice actually operate. (Jasanoff, 2004; Latour, 1999)

Quines philosophical positions – holism and underdetermination – inspired to theoretical inventions that almost have become theoretical common sense in the humanities and social sciences. My ambition in this paper is to show that Quine thesis also can be applied as a general framework for interpreting visuality in the sciences. The visual turn in the sciences has evoked anew questions of ontology – what exists - that concern the relation between the pictures factual basis and the completed representation. Quines thesis can be helpful to establish a vocabulary that can go *beyond* the truth questions and instead "making the visual visible in philosophy of science."[18] As will be shown in my paper, the visualized illustrations of the molecule consist of

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[14] https://plato.stanford.edu/entries/scientific-underdetermination/

[15] (Kuhn, 1962).

[16] The negative experiences from the "Science wars" between analytical philosophy and science studies during the nineties still have an impact on the relation. The fighting has ended, but with a truce that is characterized by a mutual lack of interest. For an overview of the positions, see (Douglas, 2009).

[17] References

[18] The expression is from AnnaMaria Carusi paper "Making the visual visible in philosophy of science", see Carusi 2012.

several layers of depictions that in the end are compounded to one visualization, a process that if not requires, at least invites to a holistic perspective for interpretation.

Quine's thesis of holism

Holism was a fundamental doctrine, maintained by Quine throughout his philosophical life and presented in *Two dogmas of empiricism* (W. V. O. Quine, 1951) as an alternative to the logical positivist view that each scientific proposition is endowed with an empirical content of its own.[19] He presented holism as a counter-doctrine to logical positivist reductionism:

> The dogma of reductionism survives in the supposition that each statement, taken in isolation from its fellows, can admit of confirmation or infirmation at all. My counter suggestion, issuing essentially from Carnap's doctrine of the physical world in the *Aufbau*, is that our statements about the external world face the tribunal of sense experience not individually but only as a corporate body. But the total field is so undetermined by its boundary conditions, experience, that there is much latitude of choice as to what statements to re-evaluate in the light of any single contrary experience. No particular experiences are linked with any particular statements in the interior of the field, except indirectly through considerations of equilibrium affecting the field as a whole. If this view is right, it is misleading to speak of the empirical content of an individual statement - especially if it be a statement at all remote from the experiential periphery of the field (W. V. Quine, 1951, p. 39f).

In this famous quotation Quine states that the confirmation of a statement, i.e. that is epistemologically justified, can only be done in relation to other statements. He is defending the principle that the truth of a single statement can only be settled when situated in context. Holism is a form of epistemological contextualism. Like the other questioned dogma – reductionism - Quine regarded his point as quite obvious, as a view that most philosophers and scientist would agree on; holism is almost common sense.[20] It rests on an expanded notion of experience that includes the knowledge of nature provided by mathematics. This feature makes Quines holism a strong epistemic position as a general framework for the natural sciences that have their base in mathematics; algorithms, equations, formulae as well as pictures rest on mathematics. John Shand

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[19] The secondary literature on Quine is huge. I am indebted to articles by Lars Bergström and Roger Gibson in (W. V. Quine et al., 1990) and Rogério Passos Severo in (Severo 2006) and (Severo, 2008).

[20] Quine questioned reductionism with similar arguments as he did with holism. A significant statement is: "The dogma of reductionism survives in the supposition that each statement, taken in isolation from it fellows, can admit of confirmation or infirmation at all. My counter suggestion, issuing essentially from Carnap's doctrine of the physical world in the *Aufbau*, is that our statements about the external world faces the tribunal of sense experience not individually, but only as a corporate body" (W. V. Quine, 1951) p. 38.)

emphasizes that "in general Quine's idea is that whole body of knowledge is at issue when a theory is tested by observation. The response to an anticipated observation is not a matter of following an exact rule… some sentences or formulations – especially those of mathematics are so thoroughly involved that it would involve a wholly impractical overhaul to change those." Mathematical sentences are "at the center of the fabric of necessary truths"(Shand, 2006a, p. 22).

I suggest that Quines holism is valid for interpreting scientific visualisations. His holism holds also for visualized science as a complex practice that includes "observation, measurement, description, analysis, and demonstration" (Pauwels, 2006, p. xii). Quine's position does not imply any objectivist view of the world; an opinion that is commonly and pejoratively ascribed to analytic philosophy as well as post-analytic philosophy from a sciences studies perspective.[21] Instead he takes a position against an essentialist objectivism. How should we accommodate the empiricist position that Quine hold throughout his philosophical career with the intervening and inventive features of computer generated visualizations in the sciences? He stated his position in *Two Dogmas* more radically than what today perhaps is remembered:

Physical objects are conceptually imported into the situation as convenient intermediaries – not by definition in terms of experience, but simply as irreducible posits comparable epistemologically, to the gods of Homer. … But in point of epistemological footing the physical objects and the gods differ only in degree and not in kind. Both sorts of entities enter our conception only as cultural posits. The myth of physical objects is epistemologically superior to most in that it has proved more efficacious than other myths as a device for working a manageable structure into the flux of experience (W. V. Quine, 1951, p. 44).

He continues to exemplify with objects at the atomic and subatomic level, forces that make boundaries between energy and matter obsolete, and repeats that they epistemologically are myths on the same footing as physical objects and gods (ibid. p. 42 or 45). In the end of the article he reiterates his message:

Total science, mathematical and natural and human, is similarly but more extremely underdetermined by experience. The edge of the system must be kept squared with experience; the rest, with all its elaborated myths or fiction, has as its objective the simplicity of laws (Ibid. 42).45

[21] For a representative statement see (Pauwels, 2006) p. vii, " It is clearly not the objective of this volume to call upon or resuscitate such outmoded and static views or science as an objective body of knowledge that leads to absolute certainty or truth."

In the above quotation Quine introduced a new concept that gave rise to quite intensive philosophical polemics and fuel debates about scientific realism, namely the concept of underdetermination.[22] In the back mirror, it has similar analytic qualities as holism; it can be used as a general framework for dealing with complexities in the visual representations of science. It also opens for acknowledging the epistemic affinities between post-analytic philosophy of science, science studies and the humanities that have been veiled in rhetoric the recent decades.[23]

Quine's position accords with perspectives in current STS-studies, the ontic turn as an analytic practice to balance "the new materialism" that have treated the physical identity and durability "in short all traits that qualify a certain entity as material" … " to assign priority or causal primacy to the 'materiality of the objects".[24] According to Steve Woolgar and Javier Lezaun "materiality needs be understood as the contingent upshot of practices , rather than a bedrock reality to be illuminated by an ontological investigation" (ibid). Quines holism emphazises the convergence of hypothesis, theories and beliefs. Reality is far from a "bedrock reality", rather a flux of non-constitutive entities. Nevertheless, Quine maintained the necessity to share a vision of the world, in a realistic sense; ideas can't exist before the vision.

Quine's thesis of underdetermination: the ontological turn

The most detailed presentation about theories underdetermination "On empirically equivalent systems of the world" was published in *Erkenntnis* (EESW), (W. V. Quine, 1975). Underdetermination can only occur when the theory has a certain level of theoretical complexity abstracted from the observations. An empirical theory cannot be underdetermined. In the case the obscurities are about linguistic indistinctness it can be solved through improved conceptual strictness. Otherwise all translated theories could count as alternatives. Theories might also be excluded by choosing the simplest of available theories.

In a general version the underdetermination thesis asserts that irrespective how well observations confirm a theory, there might exist other theories that support the same

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[22] With hindsight one can notify a tension between theoretical praxis of contemporary science studies that with few exceptions holds the position that science is determined by practices or in Quine's vocabulary, experience. Quine keeps open for an underdetermination which is rare within the STS practiced paradigm. See (Knorr-Cetina, 1999).

[23] One example is the intensive but separated discussion about social constructivism in analytic philosophy, history of science, science and technology studies. The high degree of academic specializations and harsh boundaries between especially analytic philosophy and sociology (dating back to the strong program in Edinburgh in the 1970s) have kept the fields apart.

[24] Woolgar and Lezaun (2013) "The wrong bin bag: A turn to ontology in science and technology studies?" p. 326.

observations. Observations are not sufficient for determining which theory is true. Researchers can agree on the empirical observations, still have completely different opinions how to interpret the observations. Why, the theories are empirically equivalent as they comprise the same empirical content. The condition is that the theory is convertible to tests or experiments. If the tests verify both theories they are equivalent. According to Quine, the very crucial question is whether they are logically equivalent, which would mean that two different versions of natural reality existed.

Quine maintained that conflicts between empirical equivalent theories would occur sooner or later. In EESW, he insisted that these types of conflicts were not about underdetermination. Underdetermination occurred only when empirically equivalent theories but logical incompatible theories not could be made equivalent if the predicates were reformulated. According to Quine it remained an open question whether empirical equivalent theories not also could be construed as logical equals (W. V. Quine, 1975, p. 327) s. 327. What was then the point to insist on underdetermination? Quine again:

> Failing that, a last-ditch version of the thesis of under-determination would assert merely that our system of the world is bound to have empirically equivalent alternatives which, if we were to discover them, we would see no way of reconciling by reconstrual of predicates. This vague and modest thesis I do believe. For all its modesty and vagueness, moreover, I think it vitally important to one's attitude toward science. What it says in effect is just that there are undiscovered systematic alternatives much deeper and less transparent than, for instance the Poincaré example (W. V. Quine, 1975).

Quine avoids emphasizing factual logical incompatibility. The thesis has a normative value, to uphold a non-dogmatic and open attitude related to the sciences description of the natural world. In the later works, the formulations about logical incompability are replaced by formulations about "translatability." Quine's underdetermination thesis ends up as an ideal or normative idea what ought to characterize a scientific attitude.

It becomes evident when Quine discusses underdetermination in relation to the concept of truth.[25] If two theories are logically incompatible, one must be false. However, if the question about logical incompability is neglected, if two theories are empirically equivalent both theories can be regarded as true. An *ecumenical* attitude is reasonable. In his remaining philosophical writings Quine hovered between this ecumenical attitude and what he named secterian attitude. The last words are presented in *Pursuit of Truth* (W. V. Quine, 1992) where the starting point is two empirically equivalent theories.

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[25] See (W. V. Quine, 1981) where Quine defends both positions in the same essay.

One possible attitude to adopt toward the two theories is a *sectarian one,* as I have called it: threat the rival theory as in the preceding case, by rejecting all the contexts of its alien terms. We can no longer excuse this unequal treatment of the two theories on the ground that our own is more elegant, but still we can plead that we have no higher access to truth than our own evolving theory, however fallible… The opposing attitude is the *ecumenical* one, which would count both theories true. Its appeal is empiricism: reluctance to discriminate invidiously between empirically equivalent and equally economical theories (W. V. Quine, 1992, p. 99).

In the continued text Quine asks whether it is meaningful to uphold an ecumenical attitude which means to comprise contradictory theories about the world. In earlier texts, from the 1980s he had discussed what the position of scientific realism required.[26] We can have evidence for a certain epistemic attitude, which should be kept apart from an ontological truth position. In the latter case we can't uphold two different theories about the world simultaneously, which would mean to comprise two ontologies at the same time.

… it is a confusion to suppose that we can stand aloof and recognize all the alternative ontologies as true in their several ways, all the envisaged worlds as real. It is a confusion of truth with evidential support. Truth is immanent, and there is no higher. We must speak from within a theory, albeit any of various (W. V. Quine, 1981, p. 21f).

The underdetermination of theories is dissolved into two different attitudes, on the one hand an epistemic openness depending on the evidences, on the other hand an ontological realism where only one position is imaginable as true, from the subjective point of view. The disagreement that feeds opposing versions about the world is due to limits in human capacity to interpret the world. At the bottom line there exists only one world:

The fantasy of irresolubly rival systems of the world is a thought experiment out beyond where linguistic usage has been crystallized by use. No wonder the cosmic question whether to call two such world systems true should simmer down, bathetically, to a question of words. Hence also, meanwhile my vacillation. Fare these conventions as they may, the rival theories describe one and the same world. Limited to our human terms and devices, we grasp the world variously (W. V. Quine, 1992, p. 100f).

Quine's thesis of underdetermination was initially formulated as part of his critique of "the widely accepted distinction between truths that are analytic (true by definition, or as a matter of logic or language alone) and those that are synthetic (true in virtue of some contingent fact about the way the world is), or simply facts. In the paper *Two Dogmas of Empiricism* (1951) widely regarded as one of the most important philosophical paper during the twentieth century this attack on logical positivism opened up for a concern for ontology, a field of non-

[26] (Gaudet, 2006) p. 108 defines Quine's scientific realism as "the view that scientific theories typically do posit entities beyond their empirical bases, and that such entities exist once the theories that posit them are admitted as true."

interest for previous analytic philosophy.[27] During his carrier he developed that distinction to be a part of general problem of human knowledge, namely that all our beliefs are linked in an interconnected web of beliefs. This holistic underdetermination theory was and still is regarded as challenge to the belief of scientific rationality. The challenge is that our web of belief is arbitrarily affected, no principal rule exists to understand scientific – or every day change of beliefs. A belief doesn't exist as an isolated box, but is linked into an interconnected web. A statement can only be understood within a wholeness.

Quines theoretical view led to apply an ontological view to his underdetermination thesis. If the thesis was valid, then a scientific realism was implausible, on a global theoretical level. Quine reply was, however a distinct no. It was a confusion to suppose that we can stand aloof and recognize alternative ontologies as true. Truth is immanent and there is no higher. The quest for objective truth is still the valid and wanted stance, complemented in the scientific practices by doing the necessary interventions to get proper representations.[28]

What is a plausible interpretation of his insistence on truth? He viewed science to be a window to the natural world, and without the struggle for truth it would be a meaningless occupation. His aim was to create philosophical resources for thinking systematically about how science makes sense of the world. The systematic thinking led to holism without neither falling into a seductive holism, nor the trap of reductionism, a thinking that display the transitional qualities in his philosophy. On the question whether we can encompass different ontological versions of reality, Quine is in line with contemporary STS research. In an article about the limits of shared visions in computational biology Annamaria Carusi discusses what can be the sources of resistance researcher upholds to maintain their own ontological version. She emphasizes that vision is not "an isolated act of perception alone, but vision is embedded in contexts of actions, interactions, purposes and motivation." (Carusi, 2011, p. 306). Traditional phenomenology made us aware about the perceptual blind spot between experiencing ourselves as both subjects and objects at the same time. When my left hand touches my right, I can experience the left hand touching the right and the right hand being touched, but not both touching simultaneously (ibid. p. 302). She claims that Merleau-Ponty with his concept of flesh tried to go beyond the dichotomy of subject and object.

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[27] https://plato.stanford.edu/entries/scientific-underdetermination/

[28] In (Hacking, 1983) representation and intervention is discussed as two complementary strategies for acquiring knowledge about nature at least since the scientific revolution.

Quine hadn't any interest in phenomenology, but one of his main achievements in breaking down the distinction between analytical and synthetic propositions was to show that the form and content dichotomy didn't have a valid philosophical foundation. For Quine this hade an important consequence, that the philosophers of science and the scientists shared conceptual language (Franklin Rudolf Ankersmit, 1994, p. 60).

Epistemology and ontology: a relation about knowing the world and asking what exists

In *Word and Object* Quine has a several chapters that intend to clarify how he viewed the relation between ontology and epistemology (W. v. O. Quine, 1960). Ontology's most general question "What exists?" "demands complete knowledge of the universe" and cannot be answered (Shand, 2006b, p. 31). Quine's basic answer points to epistemology; that the referential expressions in sentences indicate existence (ibid). In the philosophy of language elaborated and elusive discourses have discussed language's capacity to give a satisfactory answer to the referential questions, i.e. difficulties in connecting a word to an object. A rephrased ontological question that focus on the multitude of layers in the scientific practices, from theorizing, observing, classifying, communicating etc. meets the challenges that Quine conceptualized as the steps of radical translation that constantly compered the risk of referential opacity. These concepts were coined in the framework of philosophy of language, but my claim is that they in articulate the ontological complications in scientific visualizations. The different working phases in depicturing the molecule, from crystallization to the readymade visualization are neither transparent nor opaque, but requires a labor to produce the object that shares the similar artifice as language. Manifold referential challenges are present in scientific visualizations. Distinctions between the qualitative and the quantitative, subjective and objective, causal and non causal are intertwined in complex ways are as difficult to understand as language.[29] Carusi writes: "There is not a straightforward one-way pipe line through the development of visualization technology, nor through its use in a scientific settting … there is an ongoing and reciprocal inflection of quantitative/discrete and qualitative/continuous, with each modifying the other" (Carusi 2012, p. 110). From that view, post-positivistic analytic philosophy of science has the capacity to develop a vocabulary that could work in tandem with STS.

To sum up; Quines underdetermination thesis was in beginning presented as a problem if two empirically equivalent observations could be framed in two or several logical incompatible

[29] See Carusi (2012) p. 109 for these distinction that she means are specific for scientific visualizations – I mean these features are shared with language.

theories. The problem was reformulated as an open question about the meaningfulness in describing reality in different conceptual systems. Already in the 1970s he had abandoned the idea that empirically equivalent theories could be logically equivalent by translation. These rivaling conceptual systems were dependent on our human shortcomings to reach the truth, not that reality is relative or construed by our descriptions. In his last formulations he ended up with an open epistemological horizon, namely, we can never know if we can construe a translation manual that bridge possible logical incompatibility between empirically equivalent theories.

The question about underdetermination has been accompanied by constant theoretical challenge, namely the validity of scientific realism.[30] Some philosophers have defended scientific realism against underdetermination. The success of science seems to undermine the underdetermination thesis; it is an evidence for the human capacity to acquire knowledge beyond that which we directly observe. Other realist philosophers have questioned the claim that rival theories can be empirically equivalent. History of science illustrates that only a few alternative theories have been rivals. The valid standard of theory construction as simplicity, generality, fecundity and modesty has promoted one theory over another. Also the empirical content of a theory is due to the available scientific technology. Underdetermination might be a transient phenomenon (Severo 2006, p. 3).

Other philosophers have instead defended underdetermination and that it would be preposterous to assert scientific realism. The theoretical entities posited by science are only tools for reliable observations, not claims about the reality of the structure beyond our observations. For Quine, from a naturalistic standpoint underdetermination and scientific realism were not incompatible doctrines. His focus was on epistemological truth, i.e. whether valid evidence can be found for contradictory theories. [31] The question about epistemological truth led to ontology, the

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[30] See Severo 2006, p. 2ff.

[31] Putnam has called attention to the fact that it is not a contradiction to have a fixed opinion and simultaneously admit that no opinion is more justified than the other. The position can be expanded to encompass that all opinions i might be justified, not only one. According to Lars Bergström Quines position represents the latter, if one keeps truth and justification apart (Bergström. "Quine's relativism" *Theoria*, vol. 72, 2006.).

underlying foundation for epistemology; to ask what there is.[32] But the question was never whether any of the theories was true, but if *more* than one theory could be considered as true.[33]

Visualized science, holism and underdetermination: The examples from molecular protein biology

In molecular protein biology the visualizations are important research tools for both producing and communicating research result. The pictures illustrate the intervening strand in the contemporary sciences; they are not mere representations of a complex phenomenon, but explorative working tools that make sense of very complex mathematical digitalized information.

The expansion of imaging techniques within the biosciences has been particularly striking as efficient tool for theory development, not merely illustrations. For long the X-rays pictures were the only possible pictures from the body's inside. The new digital techniques provide more information, have better quality and hence handier tools in the scientific research process as well as in diagnostic medical practices. My claim is that the epistemological questions as well as the ontological questions that Quine introduced – what there is - have acquired a renewed relevance in the age of computerized scientific visualizations.

The vocabulary in use – visualizations, images or pictures - invites for conceptualizing these images as realistic depictions, that they truthfully depicture nature, as a kind of advanced photographs from the nano-world. The MRIs, the CT-scanners and the sub-atomic particle synchrotron accelerators don't take picture with an optic lens: the pictures are construed by a subatomic interaction outside the visible light spectra that the software in the computer composes to pictures. The visual presentation is a done by a complex transformation from a computer based data screened from the phenomena at hand. No optic lens is used to take photos of the molecules, but a visual model is produces by that available data which originates from measuring chemicals reactions. In effect, the collected information could be presented as a diagram, maps or sounds. The visual mode is due to the images' superior capacity for organizing and presenting the enormous data masses, generated by the techno science devices.

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[32] One of Quine first famous articles had the title "On what there is" See (Quine 1953).

[33] Quine was not interested in relativity in a non-epistemological sense, the quite obvious standpoint that it exists many different ontological perspectives on the world, cultural, religious, moral, political etc. See (W. V. Quine, 1975), p.15.

This picture of a ribosome is well-known (illustration 1). It was produced by the Medical Research Council Laboratory of Molecular Biology, at Cambridge University, headed by Venki Ramakrishnan who was awarded the Nobel prize in chemistry 2009. These high-resolution structures of ribosomes published from year 2000 and onwards, have revolutionized the field by exploring and mapping the complex interaction between DNA and proteins, named "protein translation." The task of the ribosomes is to construct the proteins as instructed by the DNA code. Successful crystallography, and electron microscopy have unveiled the precise positions and structures of the ribosomes in various states.

Illustration 1. http://nobelprize.org/mediaplayer/index.php?id=1207

In molecular protein biology after the crystallization process is successfully done the measured density between electrons are modeled into pictures in order to grasp the where the atoms are sitting in the molecule (Brändén & Tooze, 2009). (illustration 2)

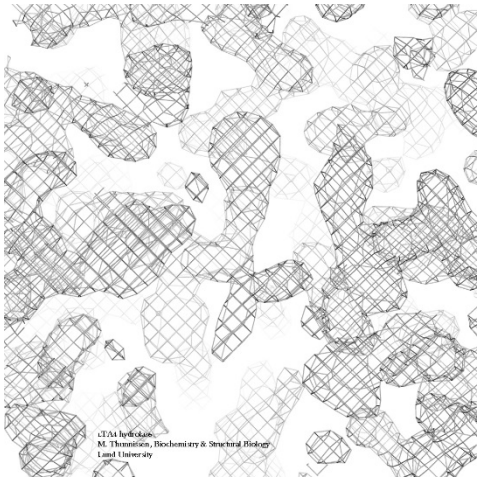

Illustration 2. Electron density molecule model

The next step is to apply another pictorial model, a structural model in order to find the specific shape of the protein molecule at display. (illustration 3).

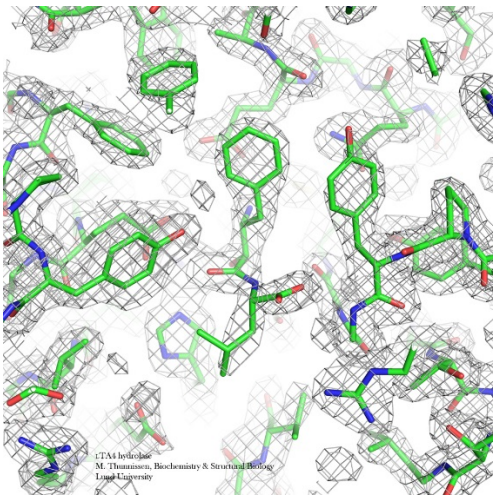

Illustration 3. Preliminary structure added on the empirical density model

The pictorial- and animation programs are research tools, designed by professional researcher, yet it is not rare to complement with for example Adobe photo shop.[34] Some of the coloring of the molecules parts are standardized, but not necessary as the colors works as explorative devices in order to find to the best final model that matches density and structure. The coloring is a part of formulating explorative hypotheses in order to find the particular protein structure in the molecule. The combined depictured properties of the molecule, the density- and the structural models, aim at getting a naturalistic model.

If we translate the validity of Quines thesis of holism from theories to pictures, holism can be interpreted as the thesis that evidence rest on compounded pictures (c.f. theories) as wholes and not on single pictures (single statements in the theory). From the perspective of the researcher the image represents simultaneously a holistic perceived reality and an epistemic fact, intermediating knowledge available for the trained judgment.

Molecular scientific pictures lack a secure empirical content taken in isolation from another. But the density- and structural models conjoined into series of pictures, give a stronger more valid epistemological foundation. Behind lurks ontological questions that can't be answered only posed, according to Quine. Underdetermination holds for complex theories, which are not empirically warranted. Applied on the interpretation on scientific pictures the underdetermination thesis is illuminating, i.e. that one set of observations or one detail of the molecule, do not determine truth value of the whole proposed protein model; a holistic approach that uses the

[34] References

underdetermination thesis can at the same time acknowledge the model's fallibility and keep the model with a preserved scientific realism (Bayer, 2007).

The new image technologies simultaneously intervene and invent nature; the bio molecular pictures don't have a present immediate reality to compare with.[35] That raises the question, if the border between fact and fiction is blurred in the contemporary bio molecular images? Even if the border may be blurred during the necessary explorative and creative research process it is not the crucial question: the goal is to construct a model that shows the complexity of the model of the explored molecule. The main task of the picture is to represent the known data in an informative way. The question whether the picture is true or not, is not the first relevant question the scientist asks. One could compare when looking at ordinary laymen photos. The first attitude towards the photo is to experience and grasp the object's condition in a wider sense, regardless if it is person, a building or a shot from nature. Only if we suspect a deceptive message is embedded in the picture, the truth questions immediately come up.[36]

The access to the nanoworld is attained by high technology facilities; challenge is to master the technical and computational facilities. A first step is to construct a theoretical model of the process in the cell, then the next step is to make a matching 3D model for how the information from the DNA is transformed to a successful production of a particular protein. The theoretical model is a controlling tool which blocks that meaning and the reference are assigned arbitrary.

A strong tendency towards an aesthetic design is present in the biomedical images; the same seductive colorful aesthetic is used as in computer games and animated movies. In science studies the similarities between the science and the arts pictures have been stressed as the twin engines of creativity. Ramakrishna's picture is a good example of these hybrid pictures – the theoretical representation is entangled with the technical intervention – and end up with apparent aesthetic qualities. A closer look at the picture shows that the picture is not intended to be photo-realistic. The bright coloring creates a distance effect. The black background frames the ribosome as a kind of display case; the depiction is similar to an exhibited museum object and further strengthens the distance effect. The magic of the picture is not producing a spell bound enchanting effect, instead the careful aesthetic in use keeps the representational effect alive. The

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[35] Similar problems hold for body images of tissues captured by CT and MRI-cameras. The pictures are composed by segmented tissue slices, known as the segmentation problem.

[36] Medical images of the body may require another approach. Often a tentative diagnosis is confirmed with the X-ray, MRI etc., which means that the truth question is relevant, but far from the only task to be achieved. In a lot of cases, for example the ultra sound examination of the baby in the uterus, the task is to get further information.

artful construction is open to epistemic reflection. It hardly gives proof for a collapse of epistemic or ontological distance in structural biology.[37] The picture is better compared with "colored diagram" and keeps the epistemic consciousness alive.

Even if the precise boundaries between science, technology and art sometimes can appear unclear, my suggestion is that the science and technology studies has enriched the discussion by enhancing the analytical sensibility towards the alterity of the scientific worlds by paying attention to features that have for long been veiled by a philosophy of science, mainly modeled as an a priori discipline loaded with foundational aspirations. Instead philosophy of science would gain to be a posteriori and have at least some focus on the practices within scientific research. The artful construction of the *experienced* reality is a common challenge for both the sciences and a philosophy of science that aspires to include and reflective of scientific practices. Quine's post analytic philosophy of science can be of use for a discussion on meaning, experience and truth in the new techno-visualized sciences. Even if the twentieth century analytic philosophy of science achieved its main results in topics related to physics and philosophy of language, the philosophical vocabulary can be re-used as a framework for an interdisciplinary dialogue on the ontological realism and anti-realism in the complex of scientific visualization.

Conclusions

Quines famous rejection of the logical positivists' analytic/synthetic distinction has implications for the interpretation of computational scientific pictures. The shared implication between the linguistic concepts in an analytical proposition and a picture is the *ambiguity*, however in different ways. Pictures are multilayered representations that relate things to things and it is not clear which component that refers and which attribute. Pictures lack subject and predicate, they are not clear cut descriptions. A picture is neither an analytical or synthetic proposition with a subject and a predicate. Quine aimed to demonstrate that neither the linguistic concepts in the analytic proposition, nor the empirical experience expressed as a synthetic description were as unambiguous, as asserted by the Vienna positivists. It is important to remember that Quine didn't reject against the meaning of the two terms, it was still meaningful to talk about analytical and synthetic truths. He rejected that truth was reducible to either of these. To conclude, one of Quine's theoretical point was that a sentence is too multilayered and complex to have a covering

[37] See Alfred Nordmann (2006) for an interesting discussion about an assumed "collapse of distance" vs. artful construction in classical natural science.

linguistic definition that totally exhaust or demonstrate the truth. I claim that this also holds for computational pictures used in the technosciences. A picture is also too multilayered and complex and cannot be reduced to a description without being open for a multitude of sets of other equally true descriptions. The explosive growth of scientific facts from organic and inorganic material, organized into illustrative pictures or animations emerge as a result of the computer generated subatomic data. The challenge in the visualized sciences is to handle the fact ladenness in the pictures, how to make a meaningful representation that cannot rest on single facts; the complexity of the whole is the challenge the researcher has to face. Truth is founded on facts but on the next level the truth questions have lost some their immediacy, on behalf of meaning and coherence. Disagreements are rarely about the fact themselves but about their meaning. Digitalization and computerization are a part of the everyday practice in almost all sciences. This has consequences for the understanding of scientific knowledge and we need reflect on how this affect the study of science.

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