Science and Theology, Dialogue between

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I. Typologies: Ways of Relating Science and Religion - II. Critical realism: the original "bridge" between science and religion - III. Further developments in methodology - IV. Anti-reductionism - V. Ontological implications - VI. Summary of critical realism and open issues.

It is fitting to commence this essay with these words from John Paul II: "The church and the scientific community will inevitably interact; their options do not include isolation. [...] Science can purify religion from error and superstition; religion can purify science from idolatry and false absolutes. Each can draw the other into a wider world, a world in which both can flourish. [...] We need each other to be what we must be, what we are called to be" (John Paul II, *Letter to Director of the Vatican Observatory*, 1.6.1988 [2], in *Papal Addresses*, p. 300). We begin with the question of methodology: how are we to relate theology and science? I will take the question as broadly including issues in epistemology and the nature of scientific and religious language, as well as issues more clearly arising in methodology per se. The past four decades have seen a variety of important such methodological proposals; here we'll briefly review some of the most promising. I believe we'll see that, though they differ significantly on key questions, they still form a somewhat continuous developmental path, leading from early insights to cutting edge research questions.

I. Typologies: Ways of Relating Science and Religion

A number of typologies have been suggested to classify various ways of relating science and religion. We will start with a brief review of them, since they illuminate the underlying assumptions often taken for granted which strongly shape the public as well as scholarly conversations. They can be quite useful both to specialists wishing to clarify subtle distinctions between positions and to non-specialists, including the media, educators, and clergy, by providing a basic orientation to the field. In some cases these ways are meant as mutually exclusive, such as "conflict" versus "two worlds"; in other cases, one way might lead to and become incorporated within another, such as "dialogue" and "integration." In some cases, each way is meant as a characterization of the relation between science per se and religion per se; in other cases, they only apply to specific topics in science and in religion.

Ian Barbour's typology, called "ways of relating science and religion", was first published in 1988 (cf. *Ways of Relating Science and Theology*, in Russell et al. [eds.], 1988, pp. 21-48), expanded slightly in 1990 and in 1997, and used to restructure the material from his 1990 Gifford lectures for a wider audience in 2000 (cf. Barbour, 1990, ch. 1; 1997, ch. 4; 2000). It remains the most widely used typology in the field. Barbour lists four types of relations, each with subtypes: "conflict" (scientific materialism, biblical literalism); "independence" (contrasting methods, differing languages); "dialogue" (boundary questions, methodological parallels); and "integration" (natural theology, theology of nature, systematic synthesis). His rich discussion is essential reading.

The 1980s saw other typologies, though they were less widely effective. In 1981 Arthur Peacocke published an eightfold typology (cf. *The Science and Theology in the Twentieth Century*, Notre Dame 1981, pp. XIII-XV). It listed both differences and similarities in realms, approaches, languages, attitudes, and objects; it also allowed for the integration of science and religion and for science to generate a metaphysics in which theology can be formulated. I later reformulated his typology as a four-dimensional model which allows for a *continuum* between opposite positions (cf. Russell, 1985; Peacocke, 1993, pp. 20-21). In 1985, Nancey Murphy appropriated H. Richard Niebuhr's classic five-fold typology of relations between Christianity and culture and applied it to science and religion. Her distinctive claim was that theology could be a transformer not only of culture in general but even of science in particular (cf. Murphy, 1985).

In the 1990's, a variety of new topologies appeared, many responding directly to Barbour's work. John Haught's 1995 typology includes conflict, contrast, contact, and confirmation (cf. Haught, 1995). The first three parallel those of Barbour; the fourth describes theology as providing some key philosophical assumptions underlying science. These include such "fiduciary" assumptions, that the universe is rational, coherent, ordered, whole, and grounded in love and promise. In Haught's (somewhat misleading) formulation, the term "confirmation" is not used to mean that science confirms theology. Haught then addresses nine key issues in science and religion and illustrates how each of his four approaches respond to them. In 1996, Willem B. Drees offered a nine-fold typology generated as three new realities (new scientific knowledge, new ideas in philosophy of science, and new attitudes towards nature) influence three distinct areas (religious cognitive claims, experiences, and traditions; cf. Drees, 1996, pp. 39-53; for an earlier, nascent version, see Drees, 1990, ch. 5). According to Drees, Barbour's typology deals with the interaction between religious cognitive claims and new scientific knowledge. In his six-fold typology, Philip Hefner includes the infusion of religious wisdom into scientific concepts, the construction of new metaphysical systems for science and the evangelical reaffirmation of traditional religious rationality. While writing on the doctrine of creation in 1991, Anne Clifford developed a detailed typology for the relations principally between Roman Catholic theology and the natural sciences, including continuity, separation, and interaction (cf. Clifford, 1991).

Ted Peters' 1998 eight-fold typology includes several refinements to Barbour's scheme. He first distinguishes between "scientific materialists," who claim that science supports atheism [3], and "scientific imperialists," who claim that science offers a path to God [4] but, like scientific materialists, argue that science alone produces genuine knowledge. He also distinguishes between Roman Catholic "ecclesiastical authoritarianism," which stretched from the nineteenth century until Vatican II and sought clerical control over secular knowledge, and twentieth century "scientific creationism," a form of Protestant fundamentalism which sees itself as genuine science though it is based on a literal reading of Genesis. Peters' typology also includes ethical overlap, New Age [5] spirituality and what Peters advocates, "hypothetical consonance." Mark Richardson's recent three-fold typology illuminates the striking difference in literary genre between: intellectual/rational texts (in which the laws of science

reveal the mind of God); romantic/affective & aesthetic/mystical texts (here science reunites us with nature as sacred); and tradition-centered texts (where scientific theories are integrated into the systematic theologies of world religions; cf. Bube, 1995; Worthing, 1996; Stenmark, 1997; Watts, 1998). Many other books and articles suggest relevant typologies of approaches to, relations between, and goals and aims for the interaction; a particularly helpful resource is the very recent textbook edited by Christopher Southgate and colleagues (1998).

II. Critical Realism: The Original "Bridge" Between Science and Religion

In his ground-breaking 1966 publication, *Issues in Science and Religion*, Ian G. Barbour laid out a series of well-crafted arguments involving issues in epistemology (the kinds of knowledge we have), language (how it is expressed), and methodology (how it is obtained and justified). Together these arguments provided the "bridge" between science and religion which has, more than any other work, made possible the developments of the past four decades. He has explored these arguments in detail since then, principally through his 1990 Gifford Lectures, together with their revisions in 1997and 2000. Barbour's pioneering vision continues to bear much of the now burgeoning flow of traffic (cf. D. Griffin, 1988; H. Rolston III, 1992). From the outset, Barbour used the term "critical realism" to stand for the specific set of arguments he developed in 1966 (cf. Barbour, 1966, ch. 6; Barbour 1974 and 1990), as have many other scholars since then. Note that many of the writers in theology and science described here draw on philosophers of science who defend what is more commonly called "scientific realism" though typically using Barbour's term, "critical realism".

Barbour viewed critical realism as an alternative to three competing interpretations of scientific theories: a) classical or "naive" realism: scientific theories provide a 'photographic' representation of the world; b) instrumentalism: scientific theories are mere calculative devices, and c) idealism: scientific theories depict reality as mental. Instead, from a critical realist perspective, scientific theories yield partial, revisable, abstract, but referential knowledge of the world. Scientific theories are expressed linguistically through metaphors and models. Drawing on Max Black, Mary Hesse, Donald Schon, and others, Barbour defined "metaphor" as an open-ended analogy whose meaning cannot be reduced a set of literal statements (cf. Barbour, 1974, pp. 12-14). Scientific models, in turn, are systematically developed metaphors. "Models and theories [...] selectively represent particular aspects of the world for specific purposes. [They] are to be taken seriously but not literally" (Barbour, 1990, p. 43).

Barbour then turned to the current discussion of scientific methodology, with major breakthroughs by such philosophers of science as N. R. Hanson, Gerald Holton, Thomas Kuhn, Michael Polanyi, Steven Toulmin, and with special emphasis on the writings of Imre Lakatos. He began with the empiricism of Carl Hempel (1905-1997), whose "hypothetico-deductive" method brought together inductivist and deductivist approaches to the construction and testing of theories vis. Popperian falsificationism. In the 1960s, this method was fundamentally recast. It was now seen to operate within both the historicist and contextualist elements which characterize the scientific community. These elements include the "theory-laddenness of data," the presence of intersubjectivity rather than strict objectivity in scientific rationality, the structure of science through paradigms and their revolutions in the history of science, the presence of metaphysical assumptions about nature in scientific paradigms, and the role of aesthetics and values in theory choice. Scientific theories are a human construction and their conclusions are inherently tentative and subject to revision. Nevertheless, according to Barbour, they are to be assessed by four criteria which are reasonably trans-paradigmatic: agreement with data, coherence, scope and fertility (cf. Barbour, 1990, pp. 33-35; 1966, ch. 6; 1974, ch. 6).

Barbour used these criteria to articulate what he called a "critical realist" theory of truth. Like classical realism, the meaning of truth in critical realism [6] is correspondence with reality and the key criterion of truth [7] is agreement of theory with data. But we often have only indirect evidence for our theories; moreover, networks of theories are tested together. Thus internal coherence and scope also serve as criteria of truth, as stressed by rationalists and philosophical idealists. Even this is insufficient when competing theories are equally coherent and comprehensive; hence fruitfulness serves as a fourth criterion of truth, as pragmatists, instrumentalists and linguistic analysts stress. Thus intelligibility and explanatory power, and not just observableness or predictive success, is a guide to the real (cf. Barbour, 1966, pp. 170-173).

Turning to philosophy of religion, Barbour constructed a similar defense of critical realism. Here his sources in religious epistemology, methodology and language include the writings of John Wisdom, John Hick, Ian Ramsey and Frederick Ferré (cf. Barbour, 1990, chs. 2-3; 1966, chs. 8-9; 1974, chs. 4-9). With these arguments in place, Barbour was prepared to make his crucial, "bridging" methodological claim: "the basic structure of religion is similar to that of science in some respects, though it differs at several crucial points" (Barbour, 1990, p.36). Similarities: Both science and religion make cognitive claims about the world using a hypothetico-deductive method and a contextualist and historicist framework. Both communities organize observation and experience through models seen as analogical, extensible, coherent and symbolic, and these models are expressed through metaphors. Differences. But there are important differences in the "data" of religion compared to that of science (cf. Barbour, 1990, ch. 2). Religious models serve non-cognitive functions which are missing in science, such as eliciting attitudes, personal involvement and transformation. Moreover, compared to science, where theories tend to dominate models, in religion models are more influential than theories (cf. Barbour, 1990, pp. 46-47, 65). Religion lacks lower-level laws such as those found in science, and the emergence of consensus seems "an unrealizable goal." Religion also includes elements not found in science such as story, ritual, and revelation through historical events.

Barbour's argument culminates in his use of paradigm analysis to place science and religion on a continuous spectrum in which both display "subjective" as well as "objective" features, though the former are more prominent in religion and the latter in science. The subjective features include "the influence of theory on data, the resistance of comprehensive theories to falsification, and the absence of rules for choice among paradigms". Objective features include "the presence of common data on which disputants can agree, the cumulative effect of evidence for or against a theory, and the existence of criteria which are not paradigm-dependent" (cf. Barbour, 1974, ch. 7; Barbour 1990, p. 65). It is the dynamic tension between similarities and differences, and between subjective and objective features in both science and religion, that together make Barbour's analysis so original and fruitful.

Yet even while Barbour was developing this position, scientific realism was being challenged in a number of ways. Though Thomas Kuhn (1922-1996) had focused primarily on factors internal to the scientific community, sociologists from the 1970s on explored the social construction of science. These externalist accounts of science emphasized the social history of science and the variety of political and economic influences on science. According to one school (the "strong program"), the theory-ladenness of data and the underdetermination of theories by evidence heavily influence the formation and content of scientific theories and the ways they are assessed (cf. Bloor, 1976; Rudwick, 1981; Hesse, 1988). At the same time, Marxists argued that science is a source of power over nature and thus over people, power rationalized by appeals to the myth of objectivity. Meanwhile the diversity of philosophical views on realism [6] in science was growing, along with an increasing number of anti-realist positions (among realists: Putnam, 1976; Hacking, 1983; Leplin, 1984; among anti-realists: van Fraassen, 1980; Laudan, 1977; for a recent anthology see McMullin, 1988). Realists frequently argued that social and personal influences are

gradually filtered out by the methods of testing used in the sciences. Moreover, the increasing success in predictive power and technological application implies that scientific knowledge is referential. Barbour's recent assessment is that these externalist accounts provide a "valuable corrective" to the internalist view, particularly regarding the context of discovery. However, the appeal to interests is hard to document and it underestimates the constraints on theories by data and the fact that the testing of theories reduces distortions due to ideologies and interests. Finally, the charge of cultural relativism should apply to the externalist claim as well.

Barbour's arguments have been developed in significant and diverse ways by a variety of scholars. In his 1979 Bampton Lectures and in his 1983 Mendenhall Lectures, Arthur Peacocke (born 1924) endorsed critical realism in both science and religion (cf. Peacocke, 1979, 1984). In science, where challenges to realism from sociologists of knowledge were mounting, Peacocke draw on arguments for realism by Ernan McMullin, Hilary Putnam and Ian Hacking. In his 1993 Gifford Lectures, Peacocke acknowledged the diversity of positions held by scientific realists but argued for a "common core" of claims: that scientific change is progressive and that the aim of science is to depict reality (cf. Peacocke, 1993). Peacocke made a similar case for critical realism in theology, where the social conditioning of beliefs is generally assumed. As in science, theological concepts and models are partial, inadequate, and revisable, and, unlike those in science, they include a strong, affective function. Still Peacocke views them as "[the] necessary and, indeed, the only ways of referring to 'God' and to God's relation with humanity," though he stresses that referring to God [4] (e.g., the *via positiva*) does not mean describing God (the *via negativa*). Its grounding in a continuous community and interpretative tradition make it "reasonable" to accept theology's explication of religious experience, though metaphorical and revisable, as an inference to the best explanation (cf. Peacocke, 1993, pp. 11-19).

Other scholars in theology and science have taken similar approaches. According to John Polkinghorne (born 1930), critical realism is the best explanation of the success of science, the only philosophy adequate to scientific experience, and the view most congenial to scientists themselves. In his 1994 Gifford Lectures, Polkinghorne drew on Thomas Torrance and Michael Polanyi in highlight the doubly circular character of knowledge: belief and understanding are mutually entailing, and what is known and the knowledge of it are mutually conforming (cf. Polkinghorne, 1994). Scientific theories are shaped by the way things are, offering an ever increasing degree of verisimilitude as suggested by his motto, "epistemology models ontology" (cf. Polkinghorne, 1986, pp. 22-24). Polkinghorne offers similar arguments for theology, too. "From a theological perspective, all forms of realism are divinely underwritten, for God will not mislead us..." (Polkinghorne, 1994, p. 156).

Note that Polkinghorne is apparently restricting the term "epistemology" to the phenomena being observed and recorded (e.g., data and experience) whereas epistemology [8] normally includes, and is even primarily focused on, the existing theories which account for phenomena (e.g., deterministic chaos, quantum physics [9], Freudian psychology). Thus to a critical realist the phrase "epistemology models ontology" would seem more likely to mean that the theories in science, perhaps even their specific concepts and terms, refer to reality regardless of what the phenomena might suggest.

Wentzel van Huyssteen, in his earlier writings, also viewed theology from a realist perspective, claiming that "theology [...] is scientifically committed to a realist point of view" and describing the referential power of theological language about God as "reality depiction." For van Huyssteen, the hypothetical status of scientific statements become the eschatological dimension of theological statements (cf. van Huyssteen, 1989, p. 162). Thomas F. Torrance (1913-2007), too, argues for the scientific character of theology because, like the natural sciences, it adopts a method which is determined by its object. For theology, the object is God, known to us by God's revelation in the incarnation and resurrection of the

Word. Thus the theoretical structures of theology disclose knowledge of God just as the theoretical structures in science, like Einstein's general relativity, provide objective knowledge of this world. According to Torrance, natural theology can find a place within positive theology, though not as a prolegomenon to it –a view which he reports he persuaded Karl Barth (1886-1968) eventually to accept (cf. Torrance, 1969, ch. 6; Torrance, 1976).

The central role Barbour gave to metaphors, models and paradigms in both science and theology has stimulated wide discussion, too. In 1982, Sallie McFague drew directly from Barbour's work in pointing to basic similarities between models in theology and in science, but she also stressed four important differences: they provide order in theology while stimulating new discoveries in science; they more clearly carry meaning in theology than in science; and unlike in science, they are ubiquitous and hierarchical, as well as eliciting feelings and action (cf. MacFague, 1982, pp. 101-108), in theology. McFague combined this with Paul Ricoeur's notion of metaphor as "is and is not" in developing what she then termed "metaphorical theology." Using this approach she has developed new metaphors for God as Mother, Lover, and Friend, and the world as the body of God which challenge theology's patriarchal and androcentric distortions and fund her work in ecological theology.

In 1984, Mary Gerhart and Allan Russell contrasted two meanings of analogy [10]: a) as an extension of our conceptual network from a known to an unknown and b) as a new and dynamic relation between two separate networks which distorts both and induces tension. They call the latter "metaphor," concluding that the relation between science and religion is itself a metaphor. In 1985 Janet Soskice published a thorough study of metaphor in religious and scientific language, emphasizing the distinction between metaphor and model which she found conflated in Black, Barbour, Ferré and David Tracy (cf. Soskice, 1985, pp, 101-107; Soskice, 1988). Although she vigorously defended theological realism, Soskice also stressed the social and contextual nature of scientific realism, in which theoretical terms "are seen as representing reality without claiming to be representationally privileged." Theological realism, in turn, distinguishes between referring to God [4] and defining "God,"'and employs a causal theory of reference (cf. Soskice, 1985, pp. 107, 131-148). In 1988, Hans Küng applied paradigm analysis to the history of theology and compared the results to the history of science. In contrast to the way paradigms are successively replaced in science, giving it an irreversible history, in theology contrasting paradigms, such as Thomism, Reformation theology, modernity, may well coexist in history (cf. *Theology for the Third Millennium*, New York 1988, p. 156). In science the next revolution comes at the limits of the existing paradigm. In theology the "primal testimony" of Scripture [11] and the events of the history of Israel and Jesus Christ are the sources of each new revolution.

An important development has been the theme of "consonance" introduced in 1981 by Ernan McMullin. His concern was the search for a "coherence of world-view" to which all forms of human knowing can contribute. The consonance that characterizes such a world-view does not require or even expect direct support. Instead it would involve mutual contributions in a relation that is tentative and open to "constant slight shift". Beginning in 1989, I combined McMullin's idea with McFague's epistemic claim about the "is and is not" structure of metaphor to include and thus to learn from both consonance and "dissonance" between scientific and theological theories. Rather than undercutting a coherent world-view, dissonance points to the dynamic character of our world view, specifying where problems arise, shifts are required, and potentially greater coherence can be sought. Moreover, by recognizing that theories in both science and theology evolve and are eventually replaced, we can build change directly into the relation between science and theology rather than being threatened by it (cf. Russell, 1989, pp. 188, 194, 204; Russell, 1994, 1994b and 1996).

Over the past decade, Ted Peters has developed this approach in terms of what he calls "hypothetical

consonance" (cf. Peters, 1988; peters 1998, pp. 18-19). If consonance in the "strong sense" means complete harmony or accord, we might "hope to find (it), but we have not found it yet." What we do have are shared domains of inquiry or consonance in a "weak sense," but this is enough to encourage further exploration. He bases this on his critical realist assumption that theologians and scientists are seeking to understand the same reality. The qualifier "hypothetical" reminds theologians to treat their assertions as fallible and subject to possible disconfirmation as well as confirmation. Willem B. Drees, though exploring the concept of consonance, has pointed out the problematic assumptions underlying realism and a correspondence theory of truth. Instead he proposes "constructing a consonance world" which includes God's otherness and the prophetic challenge of lived values (cf. Drees, 1990 and 1993). Our religious traditions invite us to wander through, and our sciences to wonder about, the reality which transcends and sustains our lives and to engage ethically with the challenge of the future (cf. Drees, 1996, ch. 5).

III. Further Developments in Methodology

According to Wolfhart Pannenberg, the defense of the truth of Christianity since the thirteenth century has been intimately tied to the claim that theology is a science (*Wissenschaft*). In the contemporary context, Pannenberg first uses Popper to challenge the logical positivist's characterization of science. He then adopts Popper's view that scientific theories are revisable hypotheses and applies it to theology as well, though he ultimately rejects Popperian falsificationism (cf. Pannenberg, 1976). Instead he argues that theories in the natural and human sciences are to be judged by the criteria of coherence, parsimony, and accuracy. Pannenberg then draws on Stephen Toulmin (born 1922), for whom theories in history, science, and hermeneutics serve as explanations by placing facts in a broader context. For theology, the explanatory context becomes the whole of reality, including the future. The resurrection [12] of Jesus plays a pivotal role in Pannenberg's methodology by proleptical revealing the future as eschaton. Pannenberg then developed a criterion for acceptability of both theological and scientific theories: the most adequate theory is the one that can incorporate its competitors. Conflicting religious traditions can thus be judged by their ability both to conceive of the whole of reality as it is proleptically revealed and to provide an explanation which more fully incorporates all that we know of it than do other traditions (cf. Murphy, 1990, ch. 2).

In 1990, Nancey Murphy criticized Pannenberg's methodology, claiming that Pannenberg cannot answer the Humean challenge to theological rationality. Hume's point of view is incommensurable with Pannenberg's, and thus cannot be incorporated into Pannenberg's system, as Pannenberg's own methodology requires. As a more adequate alternative she recommended the adoption of Imre Lakatos's methodology of scientific research programs, with its central core and surrounding belt of auxiliary hypotheses. According to Lakatos, we should judge the relative progress or degeneration of such research programs on the basis of their ability to predict and corroborate novel facts (cf. Murphy, 1990, chs. 2-3). Murphy then offers a crucial modification of Lakatos' conception of "novel facts": "A fact is novel if it is one not used in the construction of the theory T that it is taken to confirm... [that is] one whose existence, relevance to T, or interpretability in light of T is first documented after T is proposed" (*ibidem*, p. 68). This modification allows Murphy to apply Lakatos's methodology to theology, to decide rationally which theological research programs are empirically progressive, and thus to complete the argument for the scientific status of theology.

Philip Clayton (1989) has also advocated the theological appropriation of Lakatosian methodology. Clayton views "explanation" as the key concept embracing both the natural and social sciences and, ultimately, theology –one with sufficient diversity to span vastly differing disciplines while retaining an underlying unity. Here the revisionist, contextualist, and historicist arguments in recent philosophy of

science become crucial. In the natural sciences, where one interprets physical data, the truth of an explanation is pivotal. In the social sciences, however, where one interprets both physical data and the experience of actor-subjects (i.e., the "double hermeneutic"), explanation means "understanding" (*Verstehen*). Theological explanations, then, are subject to validation not by verificationist / foundationalist standards, but by intersubjective testability and universalizability, as performed by the disciplinary community. Clayton supports his case by relying on the discovery / justification distinction: religious claims can be truthful even if their sources are in social, and not just physical, data. The key, though, is Lakatos' requirement that a previously specified set of criteria is held by the community by which competing explanatory hypotheses can be assessed, including the stipulation of "novel facts."

Over the past decade, Murphy and Clayton have offered important critiques of their corresponding positions which have further revealed the layers of complexity that underlie theological rationality. Meanwhile, Murphy's approach has been implemented in discussions of theological anthropology by Philip Hefner (1993) pragmatic evaluation of religion by Karl Peters (1977), and the theological implications of cosmology in my work (cf. Russell, 1993) I believe that further pursuit of the suggestions by both Murphy and Clayton is an extremely important task at the frontiers of theology and science today (further developments in Clayton and Knapp, 1996; Murphy and Ellis, 1996; Murphy, in Richardson and Wildman, 1996).

IV. Anti-Reductionism

In an effort to understand more clearly the types of relations that exist between different scientific and theological disciplines, numerous scholars in theology and science have focused on the issue of reductionism [13]. Scholars now generally recognize several types of reductionism, with most rejecting its stronger forms in favor of a non-reducible, hierarchical model of disciplinary relations. Others, however, reject the foundationalist overtones of this model and opt instead for non-foundationalist approaches.

In 1974, Francisco Ayala identified three distinct types of reductionist theses: a) Methodological reductionism is both a research strategy for studying wholes, such as cells, in terms of their parts, such as macromolecules, and for applying successful theories in one area, such as Darwinian evolution [14], to other areas, such as sociology or religion. b) Epistemological reduction is the claim that processes, properties, laws [15] or theories found in higher levels of complexity, such as the neurosciences, can be derived entirely from those found in lower levels of complexity, such as biology, and, ultimately, physics. c) Ontological reductionism is the view that higher-level, more complex entities are nothing but complex organizations of simpler entities, i.e., the whole is "nothing but" the sum of its parts (cf. Ayala and Dobzhansky, 1974, *Introduction*).

Ayala's analysis has been widely used in theology and science beginning as early as 1976, when Peacocke gave an extensive treatment of reductionism (cf. Peacocke, 1976). In a recent essay, Murphy has added a fourth type: d) Causal reductionism asserts that all causes are "bottom-up"; the characteristics and processes of the parts entirely determine those of the whole. She has also clarified an ambiguity in Ayala's description of ontological reductionism. According to Murphy, ontological reductionism per se is the view that no new kinds of "metaphysical ingredients" need to be added to produce higher-level entities from lower-level ones. It rejects the existence of "vital forces" or "entelechy" in the life sciences, as well as mind or soul as the basis of consciousness. Murphy then adds a fifth type of reductionism: e) Reductive materialism is a stronger claim than ontological reductionism, insisting that "(only) the entities at the lowest level are really real; higher level entities [...] are only composite structures made of atoms"

(cf. Murphy in Russell et al., 1998, pp. 446-447). We can thus reject reductive materialism [16] by arguing that higher-level entities are "as real as" the entities that compose them, and we can do so while agreeing with ontological reductionists in rejecting vitalism and other ontological dualisms.

Most scholars in theology and science, while accepting the importance of methodological reductionism in science, view epistemic reductionism and reductive materialism as undercutting the credibility of higher-level disciplines and supporting the "conflict" model between science and theology. To counter this, they typically argue that the academic disciplines form a non-reducible hierarchy, starting from physics at the bottom and moving upwards through chemistry, biology, physiology, the neurosciences, the behavioral, psychological and social sciences. The ordering of the hierarchy reflects the increasing complexity of the phenomena being studied; more importantly, it allows both for rules of constraint and genuine emergence. Constraint implies that the laws, processes and properties at lower levels, such as physics and biology, constrain the laws, processes and properties at upper levels, such as psychology or ethics. Thus the laws of chemistry must be consistent with, and not contradict, the laws of physics. Emergence implies that upper levels are partially autonomous; they include new laws, processes and properties which cannot be fully reduced to, explained away by, or derived from those of the lower levels. The ordering of the sciences in the hierarchy corresponds roughly to the rise of ever more complex physical and biological systems during the history of the universe, including galactic, stellar and planetary development, and eventually molecular and evolutionary biology.

As early as 1979, Arthur Peacocke (1979) described such a hierarchy of disciplines, drawing on the writings of M. Beckner, M. Polanyi, and E. Nagel along with Ayala and T. Dobzhansky. By 1993 he had foliated the hierarchy into two dimensions: vertically it consists in four levels of increasing complexity (the physical world, living organisms, the behavior of living organisms, and human culture) while horizontally it depicts systems ordered by part-to-whole hierarchies of structural and/or functional organization (eg., in biology: macromolecules, organelles, cells, organs, individual organisms, populations, ecosystems) (cf. Peacocke, 1993, ch. 12; cf. also Peacocke, 1986, ch. 1). Peacocke's analysis undoubtedly reflects the broad consensus of the scientific community.

A key issue, though, is the place and role of theology in the hierarchy of knowledge [17]. Peacocke tends to place theology at the top of the hierarchy. As the all-inclusive study of God, humanity and the world it cannot be isolated from, but instead it should seek to integrate, all that we know from the rest of hierarchy. Moreover, by putting theology at the top, it will be maximally constrained by the rest of human knowledge. Moreover, by placing theology at the top of the hierarchy, it is maximally constrained by, and responsible to, the discoveries and conclusions of the other disciplines (cf. Peacocke, 1993, ch. 12). In a recent proposal, Nancey Murphy and George Ellis suggest that the hierarchy be modified into the shape of a "Y". The hierarchy starts with physics and moves up to chemistry and biology. Here, though, the hierarchy splits, with one branch leading to levels which study more encompassing wholes, including geology, ecology, astrophysics and cosmology, while the other leads to levels which study more complex systems, including psychology, the social sciences, and ethics. An inverted "Y" then rejoins lines from cosmology and ethics to end in theology (cf. Murphy and Ellis, 1996, pp. 65, 86, 204). A crucial ingredient of their argument is that the higher levels in the scheme complete the lower levels by offering answers to key questions raised by them. This gives theology an essential role in the overall system: "A single theory of divine purpose answers the ultimate questions arising from each branch of the hierarchy" (*ibidem*, p. 204).

Causal reductionists, however, might allow for a hierarchy of disciplines while still claiming that all causality is bottom-up. Even if higher level theories describe the regularities of their phenomena in apparently irreducible ways, the possibility of causal reductionism remains, as exemplified in the

mechanistic philosophy of the 18th and 19th centuries. To counter this, a variety of scenarios have been explored in which processes at upper levels actually do influence processes at the lower levels. These include "top-down causality," "whole-part constraint," and "supervenience" (cf. Murphy, 1996, ch. 3).

Some scholars in theology and science, while accepting the preceding arguments for an epistemic hierarchy of disciplines, reject the foundationalist assumption that often accompanies it. Foundationalism is one of the central characteristics of the modern period. It is the assumption that, like the foundations of a building, undeniable facts (following Humean empiricism) or "clear and distinct ideas" (following Cartesian idealism) provide an indubitable foundation for all of knowledge in each discipline; from them all other epistemic claims within a discipline, or even between them, must be deduced or justified. In its place, Murphy, for example, adopts W.V.O. Quine's non-foundationalist or holist approach. Here systems of knowledge are pictured more like a web or net than a building, with each level in the hierarchy of disciplines forming its own web. Core theories that characterize each discipline lie at the center of the web; they are indirectly connected to the edge of the web and its ties to the appropriate facts and experiences. As before, both constraint and emergence operate between the disciplines (cf. Murphy, 1996, ch. 3; Murphy in Richardson and Wildman, 1996, pp. 105-120).

V. Ontological Implications

We now face what is perhaps the most challenging question of all: what is an appropriate ontology in light of these epistemic schemes? Most writers in theology and science seek to avoid two extreme positions: monism in the form of either reductive materialism or absolute idealism, and dualism in the form of vitalism (life is a separate, nonmaterial entity, principle or agency) or Cartesianism (mind and body are independent realities). However, there are several possibilities which reject both of these forms of dualism and monism while still remaining monist in character. The three most prominent include: a) emergentist monism (nonreductive physicalism, ontological reductionism): There are genuinely new properties and processes at higher levels of organization, but the world is still composed strictly of physical matter (i.e., matter as described by physics); b) ontological emergence: The new properties and processes that emerge at higher levels of organization indicate that the ontology of the world, though monistic, cannot be reduced to that described by physics alone. The ontological unity or monism of complex phenomena is thus intrinsically differentiated (as suggested by the term "dipolarity") c) organicism (panexperientialism / process metaphysics): Every real event or "actual occasion" includes the capacity for experience ("prehension"), and thus a mental "pole", although this mental aspect produces consciousness and self-consciousness only when sufficient biological complexity have evolved in the form of coherent societies of actual occasions. Panexperientialists frequently reject 'emergence' as a "category mistake," thereby sharpening the difference between this approach and the preceding two (cf. Birch in Russell et al., 1998).

One can find scholars in theology and science who endorse different combinations among these approaches to epistemology and ontology. Peacocke, Polkinghorne and Barbour, for example, accept the hierarchy of the sciences though they differ on its ontological implications (emergentist monism, dipolar monism, and panexperientialism, respectively). Murphy and I work with non-foundationalist epistemologies, but she prefers nonreductive physicalism while I favor ontological emergence. On the other hand, some theists, such as Richard Swinburne and Sir John Eccles, adopt both epistemic and ontological dualism. The differences between these positions is relatively minor, though, when compared with the views of atheists such as Richard Dawkins or Peter Atkins who represent the "conflict" model of science and religion and defend both epistemic reductionism and reductive materialism.

Finally, then, philosophy can be seen as functioning in at least two distinct ways in the theology and science conversations. It can provide an overarching synthesis, a complete metaphysical framework that is, according to Whitehead, "consistent and coherent, adequate and applicable" to all fields of knowledge. Examples include William Stoeger's use of neo-Thomism or Barbour's use of process philosophyas providing a broad arena for relating a series of theological issues and a diversity of scientific fields. Such systems allow one to ask very general questions about nature and draw on, and smoothly integrate, a variety of sciences for distinctive answers. The difficulty comes when the system no longer suits changes in scientific theories, for a metaphysical system is usually not open to a "quick fix," or when the metaphysics limits rather than facilitates the theological agenda and its engagement with science.

On the other hand, philosophy can serve a more limited goal: it can provide specific terms and concepts, such as space, time [18], matter [19] and causality, that are shared by differing disciplines and carry similar meanings without embedding them in an overarching metaphysical framework. Examples include Peacocke's use of "law and chance" in both scientific areas such as biological evolution and in the doctrine of creation, and Polkinghorne's use of openness in relating chaos and complexity in nature to the possibility of divine action in the world. On the one hand, a philosophical analysis of scientific cosmology can point to the contingency and rational intelligibility of the universe [20]. These presuppositions may be imported into theology where they the become relevant to the doctrine of creation [21]. It can also mediate a concept of "nature" from theology to one underlying the natural sciences. The difficulty with this approach, on the other hand, is that, without a single overall and unifying system, there may be pervasive questions underlying the entire relationship between theology and science which cannot be addressed by the fragmentary connections offered by individual terms and concepts, and the theological reconstructions in light of science may be more piecemeal than broadly coherent.

VI. Summary of critical realism and open issues

Over the past four decades, the predominant school of thought among scholars in theology and science, particularly of those coming from a liberal theological perspective, has been critical realism. The term stood for a "packaged deal" whose elements were brought together from a variety of various philosophical contexts. They include : a) the ubiquitous role and complex epistemic structure of metaphor in all language (against literalism and expressivism); b) a Hempelian hypothetico-deductive methodology embedded in a contextualist / explanatory and historicist / competitive framework (against positivism, empiricism and instrumentalism); c) a hierarchy of disciplines with both constraints and autonomy (against epistemic reductionism); d) a commitment to referentiality, whether of individual terms or of entire theories (against some aspects of the sociology of knowledge), and with it a theory of truth combining correspondence, coherence, and pragmatism; and yet e) a genuine division over metaphysical issues, whose most representative alternatives are emergent monism versus panexperientialism. Each of these elements, of course, raised complex issues that were highly debated. Still there was sufficient agreement for these elements to form what can be called the "consensus view" in theology and science since the 1960's. For these scholars, critical realism was seen as providing the crucial "bridge" between theology and science, making possible real dialogue and growing interaction. During this period, however, each of these elements has come under criticism. Some scholars working in theology and science have stressed the difficulties facing a realist interpretation of specific scientific theories, such as quantum mechanics [9] (cf. Russell, 1988) ,as well as key theological terms, such as the concept of God [22].

Some have acknowledged the diversity of realist positions taken by philosophers as well as the continuing challenge to realism [6] by the sociology of knowledge (cf. Peacocke, 1993, ch. 12; Leplin, 1984;

Peacocke, 1984, pp. 19-22). Some have given increased attention to the diversity of models of rationality and their relative appropriateness for "science and religion" (cf. Stenmark, 1995) and the importance of differences, as well as similarities, between theology and science from the standpoint of pragmatism. Some have moved to a non-foundationalist (and in this specific sense a post-modernist) epistemology, either keeping correspondence and referentiality (cf. Clayton, 1989) or shifting to a pragmatic theory of truth (cf. Murphy, 1996). Some working with an all-embracing philosophical system, such as Whiteadian metaphysics, have developed a broad set of theological positions in light of science (cf. Barbour, 1997; Griffin, 1988; Haught, 1995) while others who make more limited use of metaphysics have developed equally broad theological arguments (cf. Polkinghorne, 1994). Other positions have emerged at increasing distances from the "consensus view." For some, a post-modernist view offers an attractive approach, drawing on Continental and / or Anglo-American sources, and for growing numbers, feminist critiques of science are crucial (cf. Drees, 1996, ch. 5). Some have abandoned realism as a whole while still finding elements of the preceding still helpful in relating science and religion.

On balance, though, critical realism continues to be defended and deployed widely in theology and science, and it continues to be presupposed by both most working scientists, by many theologians, and in much of the public discourse about both science and religion. On balance I believe it to be of enduring importance, both for its crucial role in the historical developments of the past decades and as a point of departure for future research. Whatever directions are taken in the future, it constitutes the key methodological contribution that the "first generation" gave to make discourse regarding theology and science possible today.

Read also: Epistemology [8]
Experience [23]
Realism [6]
Natural Sciences, in the Work of Theologians [24]
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Documents of the Catholic Church related to the subject:

Abbreviations and complete titles of the documents *[34]*

Gaudium et spes [35], 62, 92; John Paul II, Meeting with scientists and students in the Cologne Cathedral, 15.11.1980 [36]; Letter to Director of the Vatican Observatory, 1.6.1988 [2]; John Paul II, Discourse to scientists at the E. Majorana Center, Erice (Sicily), 8.5.1993 [37]; Catechism of the Catholic Church, Key-points concerning Faith, Reason and Scientific Knowledge, 1997 [38]; Fides et ratio, 34, 62, 104

[39]; Evangelii Gaudium, 132-134, 242-243, 257 [40].

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