COMPLEMENTARITY AND THE RELATION BETWEEN SCIENCE AND RELIGION

by Hugo Adam Bedau

About two decades ago, the idea was broached that the relation between science and religion might be understood in terms of their "complementarity." Although complementarity had been introduced by Niels Bohr in the 1920s[1] and was first applied by him to quantum physical problems, he never believed it to be a principle limited to that area of natural science. Almost from the beginning, Bohr apparently had the idea that complementarity would prove to be of widespread application in scientific and nonscientific fields alike.[2] The idea that science and religion were complementary, therefore, was quite in the spirit of Bohr's own conception of the role which he hoped complementarity would eventually play in scientific and philosophical thinking.

The early discussions showed considerable lack of clarity in the claim that science and religion are complementary,[3] not least because it was not even clear what was to be made of the central claim that quantum mechanics itself required complementarity.[4] Karl Popper has remarked, with characteristic skepticism: "I do not doubt that there is an interesting intuitive idea behind Bohr's principle of complementarity. But neither he nor any other member of his school has been able to explain it."[5] Peter Alexander concluded his critical investigation of complementarity in science and religion by saying that "we need more precise criteria for complementarity than we have been given,"[6] given, that is, by those who believed (in the words of the leading popularizer of complementarist thinking, J. R. Op-

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penheimer) that complementarity was one of those "new things we have learned . . . in atomic physics [which] provide us with valid and relevant and greatly needed analogies to human problems lying outside the present domain of science."[7] For more than a decade, a parallel but independent attempt has been made to see complementarity as the relation within religious (or perhaps theological) claims about the nature of God, of man, and of the world.[8] Yet difficulties have arisen here similar to those which prompted Popper's hesitations about complementarity in quantum mechanics and Alexander's objections to complementarity between science and religion. "The study of theological paradoxes along complementarist lines," a critic has recently declared, "seems to be founded upon what many modern physicists . . . would consider a misconception destined only to produce a quagmire of insignificant if not meaningless analogies."[9] Still, the interest among theologians, philosophers of religion, and scientists in the idea of complementarity has by no means subsided if one may judge from its continued (though by no means growing) employment in recent scholarly discussions.[10] This illustrates once again that the popularity of a philosophical idea is not primarily dependent upon the clarity with which it has been analyzed or the cogency of the argument on its behalf.

The purpose of this paper is to present an analysis of the view that science and religion are complementary on the assumption that the idea of complementarity in question is, if not identical with, at least closely analogous to the idea of complementarity introduced by Bohr into quantum mechanical theory and to assess the prospects of such an analysis of the complementarity of science and religion. The upshot of the present paper is not the assertion or the denial that science and religion are complementary; the reasons for stopping short of such a further step will be evident enough as the analysis proceeds.

Complementarity and Its Alternatives

The interest and relevance of a complementarist analysis of the relation between science and religion derive in part from the way in which it promises to offer a new solution to an old problem. In this connection, it is natural to view the complementarist's approach as the latest tactic in religious apologetics. Consequently, it will hold no appeal for those whose views are essentially agnostic or atheistic. To appreciate this new solution, it is necessary to look first at the older alternative ways in which the relation between science and religion has been understood. (For the present, let us not worry whether by "relation between science and religion" we mean the relation[s] between scientific and religious beliefs, explanations, descriptions, concepts, or

assertions; let us also ignore any distinction between first-order ["religious"] experiences, acts, and utterances, and their second-order ["theological"] explications; however, it is important to confine the relations in question to epistemological and semantic ones and to exclude any reference to causal or historical relations between science and religion.) Roughly, there are only two major possibilities. Either science and religion constitute fundamental and possibly irreconcilable alternatives to each other because they are somehow logically or empirically incompatible with each other, or science and religion do not conflict because they are not really competing alternatives. There are various ways in which these two major options have been developed, including the following four:

1. Science and religion entail conflicting judgments, and these conflicts are not resolvable except in the sense of a capitulation by one side or the other. Either one accepts science or one accepts religion (or, less globally, either one accepts a scientific position on the disputed matter in question or one accepts a religious position on it) because the respective (bodies of) beliefs are logically incompatible with each other. One is true and the other is false, and the only thing worth disputing is which is which. Religious fundamentalists and Comtean positivists or Marxist materialists alike seem to hold this view of the relation between science and religion.

2. Another version of the conflict between science and religion is that, to be sure, both are incompatible, but only when viewed from the inappropriate question-begging point of view which presupposes their amalgamation into one cognitive whole and presupposes also one universally applicable criterion of truth. Actually, science and religion are equally necessary and equally true, but each in its own sphere; their conflict is a result of a mistaken effort to allow the two to interpenetrate and interconnect when it is logical autonomy of each from the other that is required. We may call this a compartmentalist view of science and religion and of the relation between them. The medieval doctrine of the Double Truth is sometimes interpreted in such a way as to make its advocates compartmentalists in the above sense.

3. The other alternative, that science and religion do not conflict with each other, is sometimes found in a version which claims that, although religious and scientific judgments do refer to a common world (or a common event, object, or experience in the world), and although their respective judgments are really of the same logical type, each taken by itself is partial, incomplete. On this view, both are needed for a complete account of the world and our experience of it because each omits something the other includes. Arthur Koestler,

for instance, has written that religious and scientific "ways of knowing" do not "invalidate, but complete" each other;[11] and it is possible to let this or other versions of the viewpoint here in question lead to speaking of religion and science as "complementing" each other. But this would be very misleading in the present context. It would be as if we took the concept of complementary angles in geometry as our model of complementarity, that is, things complementary to each other are in some sense additive. In order to mark off this kind of view from the true complementarist's, let us say that this is the position of the supplementarist. Science and religion supplement each other.

4. Probably the most popular view among philosophers during the past generation is that science and religion "are in different logical categories and so could not possibly conflict."[12] On most versions of this view, science is or entails a set of assertions (which, to be sure, may conflict with each other), but religion does not consist of or entail any assertions; it consists of emotive, hortatory, laudatory, petitionary utterances (which may be inconsistent with each other). If so, then the two types of utterance, being in logically disparate categories, cannot be incompatible with each other after the fashion of 1 and 2, nor can they both be true as is maintained in 2 and 3. Religious utterances indeed have a point, a use, a function, but not truth value; a fortiori they present no truth claims in conflict with the truth claims of science. (Or, if religious utterances do have a truth value, they are not descriptive, explanatory, or confirmable, and a fortiori cannot compete with the truly descriptive, explanatory, confirmable claims which issue from science.) This view, curiously enough, sometimes apparently underlies the complementarity of science and religion as that relation is understood by some writers. A. F. Smethurst, for example, has written of science and religion as "complementary languages" in such a way as to suggest that he really had in mind a view such as this one.[13]

It is my position that none of these four ways is compatible with complementarism, even though there are certain points of agreement. It is the fundamental differences which require emphasis here. According to the complementarist, science and religion are equally necessary, neither can substitute for or supplant the other (which is denied by 1); both science and religion are addressed to, or have as their subject matter, one and the same thing (which is denied by 3); and both share the same logic and can yield truths in the same sense of "truth" (which is denied by 2 and 4) and, therefore, will conflict in perpetuity until the source and inevitability of the conflict is understood and resolved. To be sure, it is not claimed by the complemen-

tarist that every statement scientific in character is necessary, nor that each religious utterance can be paired with some scientific utterance such that the two are about the same thing and in logical conflict with each other (e.g., it is wholly unclear what would count as a scientific statement about a transcendent deity). Therefore, the complementarist need not claim that each scientific (religious) statement is in conflict with some religious (scientific) statement. But the complementarist's analysis does require that there are some genuine scientific utterances and some genuine religious utterances which are about the same thing (event, experience, object) and that both are necessary and true even though they appear to be in conflict with each other. These are, so to speak, the minimal conditions on the relation between science and religion which provide the occasion for a complementarist analysis and which mark it off from the chief alternatives which have claimed the attention of philosophers, scientists, and theologians.

As remarked earlier, Bohr introduced the concept of complementarity as a new theoretical principle in order to resolve well-known difficulties encountered in quantum physical theory during the 1920s. The fortunes of this concept have been closely wedded to the fate of the so-called Copenhagen Interpretation of quantum physics, in turn heavily dependent upon the writings of Bohr himself; apart from Bohr's writings over the years, we know little or nothing about complementarity as a principle, in quantum physics or elsewhere. What follows, therefore, is a summary of an analysis of the idea of complementarity in quantum physics, as understood on the basis of a single-minded effort to do justice to Bohr's views, irrespective of their current popularity or future standing among theoretical physicists.[14]

Lest the ensuing discussion appear to be a considerable digression from the professed topic of this paper, it may be useful to develop its rationale somewhat further. Let us distinguish between (*a*) the *truth* of "science and religion are complementary" depends on the truth of "quantum mechanics involves complementarity," and (*b*) the *meaning* of "science and religion are complementary" depends on the meaning of "quantum mechanics involves complementarity." I wish to affirm *b* and deny *a*. Suppose that, in the year 2000, no physicist recognizes any role for complementarity in quantum physics. Would this of itself be any reason to conclude that religion and science cannot be complementary? I do not see why it would. The most one could say is that the interest in the claim that science and religion are complementary would be somewhat diminished if it were known or believed that complementarity had no place in quantum physical (or any other scientific) theory. But since there is no scientific or philosophical

hypothesis in virtue of which the nature of the relation between science and religion depends in any way upon the conceptual structure of quantum mechanics, the abandonment by physicists of complementarity in quantum mechanics entails no consequence whatever for the complementarity of science and religion. Consequently, *a* is almost certainly false. Still, we must admit that the belief since the 1920s that quantum mechanics requires complementarity has encouraged the belief in the complementarity of science and religion. Furthermore, *b* seems true because the complementarity alleged in fields other than physics is all but unintelligible unless such allegations are based on an understanding of the term "complementarity" on the model provided by Bohr's notion of complementarity in quantum physics. After all, by what other route are we to make sense of any claim that two things, *x* and *y*, are "complementary"? Is the would-be complementarist to be allowed to mean by complementarity whatever he pleases? Obviously not, since the term is not his neologism. Is he, then, to be guided by nothing more than the analogies provided by the meaning of "complement" and cognate terms in pre-Bohr usage? If so, this resolves into the attempt to adapt the term from its use in logic, geometry, and chromatics; but there is no evidence that any would-be complementarist has had such analogies in mind. What is left, then, but a tacit reliance upon the concept of complementarity (with its aura of prestigious origin) as employed by Bohr, minus whatever is peculiar to its application in quantum mechanics? But if tacit reliance, why not explicit? This is the reasoning which convinces me that an investigation of complementarity in quantum mechanics is appropriate, even necessary, if one is to assess seriously the claim that science and religion are complementary.[15]

Complementarity in Quantum Mechanics

Bohr's Principle of Complementarity was introduced to overcome certain conceptual difficulties in quantum mechanics which arose from the fact that some of the fundamental principles of classical (macro-) physics appeared to be false when applied to quantum (micro-) physics, with the result that certain "paradoxes" emerged at the heart of physical theory. *Complementarity is designed to remove these paradoxes:* They are familiarly of two sorts. One is to be found in the fact that, whereas in macrophysics the precise position and precise momentum of a macroobject can be in principle determined simultaneously, according to Heisenberg's Uncertainty Principle such a determination for a microobject (e.g., electron) is impossible. The other paradox is the so-called duality of matter and light, namely, that whereas no macroobject can be both corpuscular and wavelike but is

always one or the other (or neither) without reference to the properties of any physical apparatus with which it is studied, in the case of microphysical theory it is well known that microphysical objects can exhibit, under suitably different experimental arrangements, either corpuscularity or wavelikeness. More precisely, whereas in the case of macrophysics corpuscularity and wavelikeness are incompatible properties, in microphysics these same properties must be understood to be compatible in a qualified sense, namely, if corpuscularity and wavelikeness are conceived as dispositional properties of microobjects, then microphysical theory tells us that any microobject has both these dispositions even though only one can be actualized at a given time. Let us call such properties "noncompatible." (Notice, by the way, that in microphysics precise momentum and precise position are also noncompatible in the same sense. In macrophysics, however, these two properties are wholly compatible.) This contrast in the compatibility relations among theoretically interpretative properties (position/momentum, wavelikeness/corpuscularity) is the crucial feature of the paradoxes which complementarity is introduced to remove.

Even though some physicists have found the paradoxical situation of position/momentum more relevant than the paradoxical situation of wavelikeness/corpuscularity, it appears that Bohr did not take this view, as his continuous emphasis over the years on both paradoxes attests. This is important to keep in mind because, of the two paradoxical situations reviewed above, only the one involving corpuscularity/wavelikeness seems to serve as a usable model when complementarity is to be applied in psychophysics (see next section) and perhaps elsewhere outside quantum mechanics. Accordingly, in what follows we shall make more precise the notion of complementarity in quantum mechanics solely by reference to its relevance for removing the paradoxical situation involving corpuscularity/wavelikeness.

The paradoxical situation, then, consists in the following facts: (*a*) the compatibility relation of corpuscularity/wavelikeness in macrophysics is violated in microphysics, that is, the incompatibility of these concepts in the former domain is in sharp contrast to their noncompatibility in the latter; (*b*) this establishes two separate and essentially contradictory conceptions of microobjects, namely, they are wavelike versus they are corpuscular; and (*c*) this in turn shows conceptual disunity at the heart of physics since the very concepts of classical physics which prove essential to understanding microphysical experimentation also render microphysics discontinuous with macrophysics.

The essence of complementarity is to be found in the way these paradoxes are removed. How does Bohr's analysis proceed? He has said, "The apparent paradoxes are removed by an examination of the experimental conditions under which the complementary phenomena appear."[16] If we continue to confine our attention to the paradox of wavelikeness/corpuscularity, a fuller description of what Bohr has in mind would go as follows: Corpuscularity and wavelikeness are theoretical concepts which, in being ascribed to an object, interpret or explain it, because they fit it into a body of mathematicophysical theory in which the concepts of wave and particle play a central and long-standing role. But the microobject being interpreted is in fact accessible to such interpretation only on the basis of certain observations, themselves dependent upon the particular properties of certain mutually exclusive experimental arrangements. This interdependence of observation, experimental apparatus, and observed entities Bohr has called a "phenomenon." One can then say that the phenomena on the basis of which wavelikeness is assigned to electrons are wholly different from the phenomena which are the basis of interpreting electrons as corpuscular. Indeed, the phenomena are complementary. To regard them as complementary removes the original paradoxical situation by insisting that the assignment of the theory-laden concepts of corpuscularity/wavelikeness to microobjects is essentially relative to certain mutually exclusive experimental arrangements. On this view, a categorical assignment of either property to a microobject—ascribing the property (e.g., wavelikeness) without mention of the observations or experimental arrangement through which they are obtained—is, strictly speaking, meaningless. The paradoxes arise precisely (though not solely) from neglect of this point regarding the necessity of reference to experimental arrangements. Seeing the phenomena in question as complementary, therefore, involves an extensive restatement of the entire relationship between microobjects, relativizing their classical theoretical properties, corpuscularity/wavelikeness, to the experimental arrangements through which these microobjects are investigated. Only by this restatement is the original paradox removed.

Complementarity is not the only way in which theoretical physicists have coped with the wavelikeness/corpuscularity paradox. Indeed, just as we have seen that science and religion can be related in ways other than complementarity, there are analogous alternatives to Bohr's complementarism in quantum mechanics. Some physicists have held that microobjects are really neither wavelike nor corpuscular. Others have held they are wavelike but not corpuscular; "particles are more or less temporary entities within the wave field." Still others

have held that microobjects are corpuscular but not wavelike; "waves are only waves of probability [which] determine 'supply' of the particles . . . in space and time." There are also those who have argued that microobjects are really both simultaneously, as in the theory of the "pilot wave." Bohr's Principle of Complementarity in quantum physics repudiates all these alternatives.

In summary, then, we can say this: Complementarity in quantum physics, so far as its application to the corpuscularity/wavelikeness case is concerned, consists in the claims that (1) the compatibility relations between the theoretical properties wavelikeness and corpuscularity differ as between micro- and macrophysics and yield utterly different conceptions of the real nature of microobjects, resulting in a fundamental paradox; and that (2) this paradox is removed by regarding certain phenomena as complementary, which in turn depends on relativizing the conception of microobjects as corpuscular/wavelike to the experimental arrangements by means of which the microobjects were investigated. The result of this conception is to disregard as "meaningless" certain questions about the "real" nature of microobjects (i.e., their properties independent of experimental investigation) and certain microphysical concepts borrowed from macrophysics unless and until they are given the required relativization.

Complementarity in Psychophysics

One of the many areas outside physics in which Bohr himself suggested that the Principle of Complementarity might be profitably introduced was in the area of psychophysics, the relation of mind and body.[17] Although his own remarks on the matter provide little basis for constructing any theory, a recent analysis by others has shown how the idea of complementarity, understood in the manner of the previous section, might be applied in psychophysics, too.[18] It is valuable to review this effort, both because it provides further opportunity to familiarize oneself with the general pattern of analysis required by Bohr's idea of complementarity and because it shows the need for some interesting deviations from the details of the analysis of complementarity in quantum mechanics, deviations which also bear upon the attempt to analyze science and religion as complementary.

Let us identify as mental any entity or event to which the subject alone has access and which is not observable as localized in some place or part of his body; let us identify as bodily any entity or event which does not permit privileged access and which does have a bodily location. Suppose also two classes of entities, such that (roughly) one of them (E_1) is what experiential statements refer to whereas the other (E_2) is the entities of a theoretical character (posited or inferred) by

reference to which scientific psychological explanations are formulated.

The distinction between E_1 and E_2 cuts across the distinction between the mental (M) and the bodily (B) as follows. As to E_1: When I mention someone else's blushing, I refer to a nontheoretical event which is also a bodily event; when I avow my own embarrassment, I refer to a nontheoretical event which is also a mental event. As to E_2: When someone refers to the logical properties of neural nets, he refers to theoretical events or entities which are bodily in character. Finally, there is reference to theoretical mental entities in a number of current psychological theories (e.g., Snygg and Coomb's "phenomenal self").

Now, it is reasonable to argue with respect to E_1 that the properties M and B as defined are incompatible, that is, that some E_1 can be M and not B or that some E_1 can be B and not M, but not both. So far as E_2 is concerned, however, this incompatibility fails. Here, M and B are only noncompatible, that is, it is possible for some theoretical entities to be mental (and not bodily) at one time but at another time to be bodily (and not mental). Hunger, for example, typically is a nontheoretical and experienced entity or state of the organism. But it is also true that, in certain contemporary experiments and physiological theories, hunger literally is assigned a locus within the hypothalamus. On such theories, hunger has the properties of being theoretical, localized, and not peculiarly accessible to the self-awareness of the hungry person. But on at least one other general psychological theory ("cognitive dissonance"), the experimental evidence is best explained by construing hunger as a nonlocalizable theoretical construct inferred only from certain self-awarenesses of hungry persons. The significance of this one example is simply that it shows how the very same state of the organism can be mental but not bodily (and vice versa) under quite different circumstances and thus shows that, for at least one kind of case, the mental and the bodily are not incompatible properties.

One can view this difference in the compatibility of the properties M and B as creating a "paradoxical situation" analogous to that which set the stage for Bohr's introduction of complementarity in quantum mechanics. If one does, then one can proceed to remove the paradox in an equally analogous way. The experimental arrangements under which the noncompatibility of M and B emerge in regard to (at least one kind of) E_2 is crucial to the assignment of these noncompatible properties in the first place, which is not true in regard to the assignment of the incompatible properties M and B to entities E_1. This justifies the judgment that an attempt to assert categorically that even

one entity E_2 is both B (but not M) and, at a later time, M (but not B) is meaningless, because the assignment of these interpretative properties has not been relativized to the particular experimental circumstances without which the decisive phenomena could not have been obtained. One can say, in other words, that by viewing M and B as complementary interpretations of certain theoretical states of the organism, one removes the paradoxical situation otherwise created by the shift in compatibility relations between M and B as one moves in assigning these properties from nontheoretical to theoretical entities.

At this point, those charitable readers who are nevertheless skeptical of a complementarist analysis of psychophysical problems may find they are of Dr. Johnson's opinion: What's remarkable is not whether the thing can be done well, but that it can be done at all. The foregoing analysis is modest in its claims in several respects, not least in allowing several deviations from the analysis of complementarity in quantum mechanics. It is true that in the present case complementarity obtains between the properties M and B (which are analogous to the properties wavelikeness/corpuscularity) whereas in quantum physics Bohr insisted upon the complementarity of phenomena. But this is not significant, because one could formulate, without distortion, complementarity as a relation between interpretations or between phenomena, and it could be shown that the two formulations have an equivalent set of conditions. The following differences cannot be accommodated so easily, however.[19] First, it is not claimed that every theoretical entity in psychology exhibits the noncompatibility of M and B, whereas it is claimed that every microphysical object does exhibit the noncompatibility of position/momentum and of corpuscle/wave. There is, therefore, a considerable reduction in scope for complementarity in psychophysics. Second, whereas the Principle of Complementarity in quantum physics can be as easily exhibited by reference to the compatibility relations of position/momentum as a wave/corpuscle, only the latter serves as an adequate model for complementarity of mind and body. Accordingly, complementarity here is dependent upon one and only one model. Third, whereas in quantum physics complementarity is used to cope with antecedent and independently identified paradoxes, the paradox in mind-body relations is somewhat contrived for the occasion, in the sense that psychophysical theorists uninterested in the introduction of the idea of complementarity would be unlikely to set up the conceptual framework in such a way as to produce this paradox in order to remove it; they certainly would find it odd to confront the claim, parallel to Bohr's for applying the "classical concepts" of wave/particle and position/momentum from macrophysics to microphysics, that it

was necessary to do so. Complementarity in psychophysics, in short, is arguably unmotivated. True, those philosophers currently worried about mind-body relationships might find a complementarist approach suited to some of their needs. But such an approach to the mind-body problem does not tie in with any current theoretical developments in scientific psychology comparable with Heisenberg's Uncertainty Principle, with which Bohr's introduction of complementarity in quantum physics has been both historically and theoretically allied (indeed, so much so that some philosophers of science have erroneously implied the two are equivalent).[20] One may view, therefore, this complementarist analysis in psychophysics as a frontier endeavor, possibly of interest to philosophers persuaded of the Identity Theory of mind and body[21] but with no more than slight justification in the theoretical tendencies of current scientific psychology.

There is, of course, no dependence whatever of the complementarity between science and religion upon the foregoing complementarity in psychophysics, any more than the latter depends on complementarity in quantum mechanics: the reasoning here is precisely that advanced at the end of the section "Complementarity and Its Alternatives." Nevertheless, as one turns from psychophysics to science and religion, the cautions and limitations of the above discussion are not exactly harbingers of success for what lies ahead.

Complementarity of Science and Religion

It was argued earlier that a complementarist analysis of the relation of science and religion needed to show (or at least assume) the following: (*a*) both religion and science are equally necessary for a complete understanding of human experience; (*b*) both have a common subject matter or reference (both are "about" the same thing); (*c*) both share the same logic—at least, both can be said to be true (in the same sense of "true"); (*d*) nevertheless, the two are not compatible with each other as they stand. We see now that it is the conjunction of these conditions (with their presupposition of different domains) which constitutes the "paradoxical situation" complementarity removes, and we also see that the incompatibility in *d* is removed by (*e*) uncovering certain "experimental arrangements" which alone make possible the application of scientific and religious interpretations to one and the same thing but which if neglected make meaningless such interpretations and which must be taken into account to "relativize" these interpretations. We also see the need for (*f*) a domain of application (a set of entities) for these interpretations where their "compatibility relations" differ from the domain in *b* (as do the compatibility relations of wave/particle and position/momentum in macrophysics in

contrast to microphysics). In addition, (*g*) one must specify precisely the domains of the complementarity relation itself (which, in the section "Complementarity and Its Alternatives" was left deliberately ambiguous as between beliefs, explanations, descriptions, concepts, etc.); until this is done, we really do not know what it is that is scientific and what it is that is religious in terms of which the complementarity of science and religion is to be expressed. All this is required for any reasonably exact analogy between complementarity of science and religion and the complementarity in quantum physics and psychophysics.

Reflection upon these conditions leads me to offer three observations. First, the disanalogies between complementarity in quantum mechanics and any currently conceivable complementarity of science and religion are enormous, so much so that a scotch verdict is the kindest judgment one can render on the claim that science and religion are complementary. Every proposed defense of complementarity between science and religion which I have seen either fails to take seriously the obligation to base itself upon the concept of complementarity in quantum mechanics, and thereby turns the claim that science and religion are complementary into a mere trope, or runs up against the kinds of objections Peter Alexander skillfully marshaled some years ago to the complementarist theories of Donald MacKay and C. A. Coulson.[22] Among the most important difficulties facing a complementarist analysis are (*a*) the identification of paradoxes between science and religion to be removed by a complementarist analysis and (*b*) the establishment of something analogous to "mutually exclusive experimental arrangements" with which to remove these paradoxes. Second, it may be possible nevertheless to recast the claim of the complementarists so as to avoid emphasis on any strict analogy with complementarity in quantum mechanics and to see it instead as a way to bring to light certain suppressed or neglected features in science and religion and their relationship. Third, even if complementarity is not a useful or a promising idea with which to understand the relation of science and religion, it may still be one, or even the best, way to analyze purely theological or religious paradoxes. At least, here there is a prima facie reason for trying a complementarist theory because there are, as many scholars have pointed out, a number of paradoxes, dilemmas, contradictions, and incongruities calling for some sort of resolution.[23] In the remainder of these remarks, I propose to concentrate exclusively upon making good my position in regard to the first of the above points.

Paradoxical Situations. Where are the paradoxes between science and religion which complementarity might be invoked to remove? We must, I suggest, find paradoxes which genuinely perplex religiously

sympathetic and scientifically informed thinkers as paradoxes involving religion and science, that is, as paradoxes which sensitive thinkers acknowledge independently of their views on complementarity. In insisting upon this, as I do, I would not wish to be taken to be demanding that by a paradox we mean only what philosophers (following F. P. Ramsey) have called "logical" or "semantical" paradoxes.[24] Perhaps it is not even necessary that we satisfy the particular structure of a paradox as explicated earlier by quantum mechanics, with its pairs of interpretative concepts and their differing domains of application and contrasting compatibility relations. But it is essential that there be some legitimate sense of paradox applicable to genuine difficulties relating science and religion; it is simply impossible to waive entirely this requirement. As a last resort, one might show at least (as in the complementarist analysis of psychophysics) that hitherto unknown or latent paradoxes between science and religion are revealed by a complementarist analysis, paradoxes which upon inspection really are paradoxical in some serious sense of that term.

A review of the possibilities is not encouraging. Some possible paradoxes are not paradoxical at all; they are not really odd, surprising, or perplexing in the least. For example, Coulson (who probably did as much as anyone to popularize the idea of the complementarity of science and religion) spoke of the "duality" of scientific and religious "accounts" of a given situation and offered as his model of this duality the apparent incompatibility between two (or more) architectural drawings of a given building.[25] Coulson, to his credit, did not claim that there was anything paradoxical in the fact that an elevation and a floor plan (or a series of elevations in different cross sections of the building) could be about one and the same edifice yet present wholly different "accounts" of it. There is nothing at all odd or surprising, much less inherently contradictory, in the fact that a three-dimensional object can be given an infinite series of projections (no two of which are identical) on a two-dimensional surface and that only with such a set of drawings can we "exhaust" all there is to show or know about the building. What Coulson overlooked is that, if a putative conflict between scientific and religious accounts could be understood on the model of duality which he offered, then it is misleading to invoke the concept of complementarity because there is no paradox to be removed. Unfortunately, Coulson gave no examples of paradoxes between science and religion which did not fit his model, nor did he give any other model whereby something more closely approaching paradox might be identified. This is a failure typical of every other doctrine of complementarity between science and religion which I have seen.

The complementarist approach has yet to bring to light any latent

paradoxes hitherto concealed or hidden between science and religion. This may be because the paradoxes which seem to occur in physics and provoked Bohr into advocating his Principle of Complementarity have such a complex structure. In particular, the contrast so crucial to setting up the paradoxes in physics, namely, between the domains of macro- and microphysics, has little suggestive value in general; instead it is an obstacle to executing a complementarist analysis in other fields. Moreover, it is not enough simply to make sense of a contrast in domains of application for pairs of variously compatible interpretations. It is also necessary—if the analogy to physics is to be a serious one—to show that it is in one of these domains where we are taught the use of the very concepts which, when applied in the other domain, give rise to paradox. This was not shown in the case of complementarity in psychophysics, and it is difficult to see how it could be shown in regard to science and religion. Perhaps a further analysis may show my judgment to be prematurely negative. Meanwhile, one can conclude only that paradoxes occasioned by the kind of logical and empirical conditions operating in theoretical physics simply have no counterpart in the relation between science and religion. Of course, one can define "scientific belief" and "religious belief" (or, instead of belief, then interpretations, concepts, etc.) in such a way as to make them incompatible under some conditions and noncompatible under others (in the sense of the section "Complementarity in Quantum Mechanics") and thereby both meet one of the conditions of paradox and give a plausible explication of the nature of science and religion. But there will be no analogy of an incompatibility between science and religion understood in this way to the kind of complex "paradoxical situation" in physics.

Even if we do find genuine paradoxes, perhaps not in the sense of the aforementioned section but nevertheless in some other intelligible sense, we will discover that it is doubtful whether those who find the paradox genuine will want it analyzed in the complementarist fashion. Consider one famous example. Traditional Christianity has asserted that Jesus the Christ is both divine and human, and classic heresies emerged from the denial or nonliteral interpretation of one or the other half of this twofold truth. In this example, the central christological dogma, we have apparently a paradoxical assertion about Jesus, and, moreover, one which goes a long way to meeting the special requirements of a complementarist analysis. Surely, for the Christian it is necessary to predicate of Jesus both the attribute of manhood and of divinity; there is no redundancy between the two (each is independent of the other); surely both descriptions are applied to one and the same historic person. Furthermore, there is

genuine paradox here, in the strong sense of the term because, for a Greek, to be divine and human is to be both immortal and mortal, whereas, for a Jew, to be divine and human is to be both worthy of worship and unworthy of worship. (Saint Paul no doubt grasped this point in his own way, for he conceded that preaching the crucified and risen Christ was foolishness to the Greeks and a stumbling block to the Jews.) Finally, we have in this example a paradox of science and religion since it is plausible to regard the predicate, "is human," as subject to scientific criteria for its legitimate application and the predicate, "is divine," as subject in a parallel fashion to religious criteria.

But is this a paradox one would want to remove in a complementarist fashion? Not, I think, if one is a Christian (but for whom else will the paradox even arise?). The Christian is bound to be repelled by the complementarist's analysis of this paradox once he understands that the effect of introducing complementarity is not only to explain away the paradox but also to do so in a devastating way. The crucial step in overcoming the paradoxes involving "classical concepts" in microphysics consists of asserting that a certain pair of statements which give rise to the paradox are, strictly speaking, meaningless. In our example, this requires us to say that "Jesus the Christ is both divine and human" is, as it stands, nonsense and becomes sensible only when the interpretative ascriptions, "is divine" and "is human," are appropriately "relativized" by whatever at this point plays the role analogous to "experimental arrangements." Now, it may be that a thoroughly modern Christian welcomes the opportunity to cope with the ancient christological paradox in this fashion, but I should be surprised if he would or that, if he is caught up in the current antitheological craze so popular among professing Christians, he would have any interest at all in a complementarist analysis. In any case, I leave it for believers to tell us whether they really want a complementarist analysis of the paradoxes between science and religion if it requires them to conclude that the christological paradox is, as it stands and speaking strictly, meaningless (and, moreover, can be made meaningful only in a special way).

The problem raised here is not peculiar to this paradox or to Christianity. If I am right, the believing religionist of whatever faith will find it difficult to feel edified by a complementarist analysis of paradoxes between the convictions of his faith and his scientific knowledge. As for the nonreligionist, no paradoxes of this sort can arise because he cannot grant the truth of any distinctively religious affirmation. This does not show, of course, that complementarity is not the answer to the paradoxes of science and religion, such as the one discussed above. But it does show that it is not the answer of the

nonbeliever, and it suggests that it is probably not the answer of any reasonably orthodox believer, either. Whether avowedly heterodoxical or heretical believers would be attracted at all toward a complementarist analysis, in preference to other theories of the relation of science and religion, remains to be seen.

Experimental Arrangements. It seems preposterous to look for any experimental arrangements through which religious or scientific experiences, or religious or scientific interpretations of "neutral" experiences, can be produced. Yet it is not absurd to look for something analogous to such arrangements as part of the normal human equipment, so to speak. Many thinkers in recent years, and by no means only (or even primarily) those sympathetic to complementarism, have suggested that the conflict between science and religion is rooted in (and can be resolved by recognition of) different experientially, temperamentally incompatible, attitudes. Just as beauty, it is said with some small wisdom, lies in the eye of the beholder, so the conflict of science and religion may lie in the attitudes of the observer.

By "attitude" here one would understand psychological states, capacities, or dispositions in terms of which persons perceive and conceptualize their environment, such that if and only if a person has at a particular time this attitude with respect to a given event, object, or situation, then he interprets it scientifically (or, if in the other attitude, religiously); and such that no one person can actualize at one and the same time both attitudes with respect to the same entity, even though he might at different times (and different persons might at the same time). Whether or not such attitudes are to be thought of as distributed throughout the population or as the special capacity only of some persons, and whether every person who has the one attitude is to be thought of as also having the other attitude, are further questions which, though important for the psychology of religion and of science, are not of importance for the purposes of a complementarist analysis. It can be made consistent with any of these alternatives.

What we might call "attitudinalizing" religion and science in this way has some attractiveness, not merely because it may be the only way to carry over the required analogy from complementarity into this area but also because it is not an implausible idea that persons differ in their capacities and tendencies to "see" the world in a scientific or in a religious way and that this tendency or capacity should be a necessary and sufficient condition of the respective scientific and religious judgments they make or accept.

However, the difficulties in making such plausibilities precise, well-founded empirically, and noncircular in their specification have yet to be surmounted. Suppose, for instance, we define "x has religious

significance for A" as (1) whatever A deems worthy of reverence, worship, unqualified esteem, "ultimate concern," or whatever evokes in A a "sense of the holy," and such that (2) A regards x as transcendent, supernatural, beyond the bounds of what is knowable by ordinary sensory perception and scientific inquiry. Let us then say that any belief, interpretation, description, or explanation is religious for A if and only if it is a belief, etc., of A's of or about something which satisfies both 1 and 2. Let us then say that x has scientific significance for A if and only if neither 1 nor 2 is true of x (i.e., x is neither reverence evoking nor supernaturalistic for A). These definitions enable us to say of any belief, etc., whether it is scientific or religious (or neither; we have not excluded this possibility). But how shall we identify the attitudes in or from which A makes or accepts judgments of the two sorts in question? If we say that R_a is whatever attitude A is in when he asserts of some x a belief satisfying the conditions (1) and (2) above, then the assertion that R_a is a religious attitude and a sufficient and necessary condition of his making or accepting religious beliefs, etc., becomes trivial. For we have not provided any independent test or identification of the attitude in question. The proper way to proceed would be, instead, to specify a set of characteristics of attitudes (e.g., by referring to some biochemical, electroneural, or behavioral characteristics of persons), show that these characteristics correlate in two sets so as to serve as criteria of two different attitudes, and then further correlate each of these attitudes with observed tendencies in persons to make or accept religious and scientific beliefs, respectively. In theory, the identification of such attitudes and such correlations is possible. But it is important to realize that, despite frequent reference to "religious attitudes,"[26] we have at present no empirical evidence to show that there is any one attitude common and peculiar to those who have religious beliefs or who accept religious judgments, much less that it is a necessary and sufficient condition of being in such an attitude to make or accept a religious belief, etc. The same is true, I would expect, concerning the hypothesized "scientific attitude"; psychological science today knows of nothing of the sort.

One experiment has been conducted recently which does give confirmation to the hypothesis that "events which are, in some sense, experienced in a highly affective way are associated with religious interpretations," whereas events which are not so experienced are associated with scientific interpretations.[27] But this experiment does not give "any information about the situation in which the same kind of experience is alternatively interpreted in a scientific and religious way."[28] Yet this is precisely the sort of possibility countenanced by the analogy with the experimental arrangements of quantum physics.

Moreover, in the experiment cited, no hypotheses were advanced or tested concerning the necessity of being in the "affective" attitude in order to give a religious rather than a scientific interpretation, though such a hypothesis is not inconsistent with the outcome of the experiment.

However, even if we were to suppose that the attitudes in question could be shown in some nontrivial fashion to exist and to play the role analogy requires for them in the complementarist analysis, there are two related consequences which are bound to give pause to anyone contemplating a complementarist analysis of science and religion who does so at least in part out of an apologetic purpose. First, any attitudinalizing of religion or of science must avoid confusing a causal-genetic explanatory approach to the beliefs, etc., which are hypothesized to issue from such attitudes, with a noncausal, justificatory approach to those beliefs. Surely, how someone comes to assert or accept a certain judgment does not seem relevant to whether and on the basis of what evidence or reasons his judgment is true; and this irrelevance of "how" to "whether" is independent of any other characteristics of the judgment and attitudes in question. But in the present context there is a second and (if that is possible) even stronger objection. The analogy with complementarity, as we saw earlier, holds that the failure to mention "experimental arrangements" leaves the ascription of properties to the "objects" meaningless or false. The required emphasis on attitudes, therefore, not only undermines (or, if one wishes, provides a new basis for) the epistemological status of religious truth claims but also goes even further in doing the same thing for what might be called the semantic status of religious truth claims. One cannot emphasize too strongly that if there are attitudes, such as those under discussion here, which alone enable a person to assert or accept religious and scientific beliefs, then any future theory of religion and of science must take this fact into account. But so far we know of no such attitudes, and it is difficult to see what advantage for either science or religion (other than the removal of alleged paradoxes) is to be gained by pursuing the hypothesis that there are such attitudes and, furthermore, that they play the role required by analogy to experimental arrangements.

Conclusion

Lawyers tell us it is "impossible to prove a negative," but philosophers since Zeno have known better. A *reductio ad absurdum* is an excellent way to prove that a certain theory (= a set of propositions) is inconsistent and, as a whole, therefore not true. In the present case, critics of complementarity have not proved (by this or any other route) that it is

logically impossible for religion and science to be complementary to each other, in the sense that no contradiction has been shown to infect the requirements *a* through *g* advanced in the section "Complementarity of Science and Religion." But this is slight solace. Complementarists have not shown that it is logically possible to meet these requirements, either. I think it is possible they should be met, but I have no proof.

Eventually, the would-be complementarist must face his dilemma. If the complementarity of science and religion is asserted to be, point for point, homologous with the paradigm case of complementarity reviewed earlier, then such a rigorous use of the term is likely to make the assertion of complementarity look highly implausible because it will require a counterintuitive or unempirical reshaping of either science or religion (or both) in order to make them complementary. But if one chooses to retain the familiar contours of both science and religion and acknowledge that this prevents anything more than a weak analogy to complementarity as that concept has been analyzed, then the assertion that science and religion are complementary becomes either implausible or trivial and unilluminating. Any philosophical analysis must avoid both pitfalls, and a reasonable man is loath to choose between them.

The net result of the present discussion offers little or no hope to those who would see any analogy to complementarity in quantum mechanics in the relations between science and religion. True, more work can be done at almost every point before finally abandoning the effort to show that science and religion can be understood on the model of Bohr's concept of complementarity. Of course, if one rejects the analysis given earlier of Bohr's idea, it may well become easier to make an application of complementarity to science and religion. But on what basis is one prepared to reject that analysis? It simply begs the question to object that the proffered analysis of complementarity in quantum mechanics must be wrong because it does not allow science and religion to be complementary.

In any event, as Bohr's influence fades with the passage of the years, and as theoretical physics continues to develop, the attractiveness of the Principle of Complementarity itself is likely to wane —unless, of course, it has proved meanwhile to be of interest and value in other scientific fields. Hume, it will be remembered, allowed his skeptic protagonist, Philo, to conclude the *Dialogues concerning Natural Religion* by remarking to the deist, Cleanthes, that perhaps there is, after all, "some remote analogy" of the cause of order in the universe to human intelligence. It is difficult to make more than this concession on behalf of the analogy we have been investigating.

NOTES

1. See Niels Bohr, "The Quantum Postulate and the Recent Development of Atomic Theory," *Nature* 121 (1928): 580–90, reprinted in his *Atomic Theory and the Description of Nature* (Cambridge: Cambridge University Press, 1934).

2. Aage Peterson, "The Philosophy of Niels Bohr," *Bulletin of Atomic Scientists* 19 (September 1963): 12–14. For other references to the influence of Bohr's idea of complementarity on fields outside quantum physics, see P. K. Feyerabend, "Problems in Microphysics," in *Frontiers of Science and Philosophy,* ed. R. G. Colodny (Pittsburgh: University of Pittsburgh Press, 1962), p. 191, nn. 7–9. I know of no evidence in Bohr's writings or elsewhere to support Dillenberger's statement that "the principle of complementarity . . . was actually taken over by Bohr from philosophy and theology" (John Dillenberger, *Protestant Theology and Natural Science* [New York: Doubleday & Co., 1960], p. 275).

3. See, e.g., John Baillie et al., *Science and Faith Today* (Guildford, Surrey: Lutterworth Press, 1953); C. A. Coulson, *Science and Christian Belief* (Chapel Hill: University of North Carolina Press, 1955); Peter Alexander, "Complementary Descriptions," *Mind* 65 (1956): 145–65; and D. M. MacKay, "Complementary Descriptions," *Mind* 66 (1957): 390–94.

4. See, e.g., Mario Bunge, "Strife about Complementarity," *British Journal for the Philosophy of Science* 6 (1955): 1–12, 141–54; Adolf Grünbaum, "Complementarity in Quantum Physics and Its Philosophical Generalizations," *Journal of Philosophy* 54 (1957): 713–27; and the symposium between D. M. MacKay and P. K. Feyerabend, "Complementarity," *Aristotelian Society: Supplementary Volume* 32 (1958): 75–122.

5. Karl R. Popper, *The Logic of Scientific Discovery* (London: Routledge & Kegan Paul, 1959), p. 456.

6. Alexander, p. 165.

7. J. R. Oppenheimer, *Science and the Common Understanding* (New York: Simon & Schuster, 1954), p. 9. In general, see chap. 5 of this book (which originated as Reith Lectures over the BBC).

8. William G. Pollard, *Chance and Providence* (New York: Charles Scribner's Sons, 1958), pp. 151–52; Dillenberger, p. 287; and William H. Austin, "Complementarity and Theological Paradox," *Zygon* 2 (1967): 365–81.

9. James L. Park, "Complementarity without Paradox: A Physicist's Reply to Professor Austin," *Zygon* 2 (1967): 387.

10. E.g., William G. Pollard, "Indeterminacy, Mystery, and a Modern Epistemology," *Zygon* 1 (1966): 181–85; Charles E. Townes, "The Convergence of Science and Religion," *Zygon* 1 (1966): 301–11; Ian G. Barbour, *Issues in Science and Religion* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1966), pp. 290–94. (Barbour showed more enthusiasm for a complementarist analysis in his earlier essay, "The Methods of Science and Religion," in *Science Ponders Religion,* ed. Harlow Shapley [New York: Appleton-Century Crofts, 1960], p. 214); I. T. Ramsey, "Religion and Science: A Philosopher's Approach," in *New Essays on Religious Language,* ed. Dallas M. High (New York: Oxford University Press, 1969), p. 52; and Ian G. Barbour, ed., *Science and Religion* (London: SCM Press, 1968), pp. 27, 72, 75.

11. Arthur Koestler, *The Yogi and the Commissar* (New York: Collier Books, 1961), p. 214.

12. Alexander, p. 164. For a recent development of such a position, see Donald D. Evans, "Differences between Scientific and Religious Assertions," in Barbour, ed., *Science and Religion,* pp. 101–33.

13. Arthur F. Smethurst, *Modern Science and Christian Beliefs* (Nashville, Tenn.: Abingdon Press, 1955), pp. 88, 109.

14. Hugo Bedau and Paul Oppenheim, "Complementarity in Quantum Mechanics: A Logical Analysis," *Synthese* 13 (1961): 201–32. Detailed citation of sources omitted in the summary above will be found in this article. For an extensive review and criticism of Bohr's position, see Feyerabend (n. 2 above).

15. MacKay (n. 3 above) and in his " 'Complementarity' in Scientific and Theological Thinking," this issue, has argued in effect that (i) complementarity is a "logical" relation, (ii) it antedates Bohr's adoption of the term, (iii) its logic deviates from that to be found in Bohr's use, and therefore (iv) we need not trouble ourselves overmuch with whether we can make sense of claiming that religion and science are complementary in a fashion analogous to that in which Bohr says that quantum mechanical phenomena are complementary. So far as the term "complement" and its cognates, including "complementarity," have any serious cognitive content prior to the 1920s, it is to be found in their employment in logic (any term, T, is the complement of any other term, T', if and only if the conjunction of T and T' exhausts the universe of discourse), in geometry (any angles, $\alpha, \beta, \gamma, \ldots$, are complementary if and only if their sum is 90°), and chromatics (any color, C, is complementary to another color, C', if and only if they are 180° apart on a color wheel, i.e., yield neutral when combined). If we attempt to state the logic of the term "complementary" based upon these sources, it would appear that the term designates a dyadic relation (even in geometry, we speak of the complementary angle to a given angle) and that in some sense or other the pair of complementary entities are exhaustive of a certain domain. However, we cannot always say that complementary entities are exclusive of each other because complementary angles may be identical (i.e., both 45°). Oddly, it is only the exclusiveness of complementary entities which MacKay carries over from pre-Bohr usage into his own definition of the concept. In Bedau and Oppenheim, all three properties are used to explicate Bohr's concept of complementarity; but they are shown not to suffice to define that concept. Since Bohr's use is continuous with the chief "logical" features of the term "complementary" antedating the 1920s, any attempt to deviate from Bohr's concept of complementarity by appeal to pre-Bohr usage is doomed to failure. I suspect MacKay's notion of complementarity is intended to be faithful neither to Bohr's concept of complementarity nor to the pre-Bohr concept (which is itself not a sound basis for consistent generalization, as I have shown above), but is intended to be an entirely new concept with a new "logic" all its own. If so, I think it is misguided on two grounds. One, and surely the chief ground, has been set out in the criticisms of Alexander (n. 3 above) and in Alexander's unpublished essay originally presented at the conference on "Science and Religion: The Complementary Hypothesis," Birmingham, England, April 1969. The other, which can be seen from a study of the literature cited above in nn. 2–13, is that the alleged complementarity of science and religion has been thought by almost all writers to be a case of the application (either by analogy or by specification) of a concept essentially like the one Bohr had introduced into quantum mechanics; no writer I have read (not even MacKay himself) uses the term as though it were an entirely new concept having only (misleading) orthographic affinities to "complementarity" as found in Bohr or to "complementary" as found in classical logic, geometry, and chromatics. Whether, therefore, (i) is true it is difficult to say; in any case, the truth of (ii) does not tend to establish anything interestingly relevant because (iii) is false; and the argument to establish (iv) is thus for several reasons unsound.

16. Niels Bohr, *Atomic Physics and Human Knowledge* (New York: John Wiley & Sons, 1958), p. 40.

17. Ibid., pp. 76–79, 91–93; also the literature cited in n. 2 above.

18. Nathan Brody and Paul Oppenheim, "Application of Bohr's Principle of Complementarity to the Mind-Body Problem," *Journal of Philosophy* 66 (1969): 97–113. The reader is referred to this article for detailed citation of sources relevant to the argument as summarized in the text above.

19. Most of the following differences were already noted by Brody and Oppenheim.

20. E.g., Hans Reichenbach, *Philosophical Foundations of Quantum Mechanics* (Berkeley: University of California Press, 1944), p. 77; and Ernest H. Hutten, *The Language of Modern Physics* (London: George Allen & Unwin, 1956), p. 191.

21. For an extensive review, see Herbert Feigl, *The "Mental" and the "Physical"* (Minneapolis: University of Minnesota Press, 1967).

22. Alexander.

23. See I. T. Ramsey and N. Smart, "Paradoxes in Religion," *Aristotelian Society: Supplementary Volume* 33 (1959): 195–232. None of the paradoxes they discuss are those between science and religion, and neither writer shows any interest in a complementarist resolution of those they do identify (though see Ramsey [n. 10 above], pp. 199–200, and the critique in William H. Austin, "Models, Mystery, and Paradox in Ian Ramsey," *Journal for the Scientific Study of Religion* 7 [1967]: 51–55).

24. Quine has recently offered a new classification of paradoxes into those which are "veridical," those which are "falsidical," and those which are "antinomies" (W. V. O. Quine, *The Ways of Paradox* [New York: Random House, 1966], pp. 3–20). The paradoxes complementarity is needed to resolve are probably of the first sort, as Brody and Oppenheim have already noted.

25. Coulson (n. 3 above), pp. 66 ff.

26. For a recent discussion of the concept of attitude in religion, see J. Paul Williams, "The Nature of Religion," *Journal for the Scientific Study of Religion* 2 (1962): 7–8.

27. Nathan Brody, "Scientific and Religious Experiences Distinguished by Their 'Affect,' " *Psychological Reports* 16 (1965): 737.

28. Ibid., p. 740.