All eligible articles published or slated for publication within the year are automatically considered for this award. The winning essay may be on any literary topic. When possible, preference should be given to essays on topics within the general areas of Victorian and/or Modern British Literature, literary criticism, or the teaching of literature.

in this issue . . .

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Schrödinger's Student

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In 1935, Erwin Schrödinger published a paper on "The Present Situation in Quantum Mechanics" in *Die Naturwissenschaften*, serialized over three issues in November and December of that year. The first installment presents the famous "cat paradox" that has become inseparable from Schrödinger's name. The second presents a theory of measurement as a challenge to the statistical predictions that govern quantum mechanics. And the third frames the emerging theory of quantum entanglement as a theory of knowledge. Schrödinger builds the scaffolding of entanglement upon the figure of a student taking an examination.

This essay aims to use Schrödinger's figure to ask how the epistemological uncertainty introduced into classical physics by quantum mechanics challenges the systems of knowledge production in the classroom and the academic environment. On the obverse I will ask how and why the classroom offers quantum mechanics a place of certainty. Considering the figure of the student as it emerges at the historical moment when quantum entanglement begins to challenge the probabilistic capacity of quantum mechanics will also allow us to reconsider the traces of the radioactive political decay glowing in the break between philosophy and science.

Both the classical mechanics of Newtonian physics and the quantum mechanics that developed over the course of the 20th century rely on models. The main difference between the classical models and the quantum models is that the latter rely on statistical analysis. This means, for Schrödinger, that the claim asserted on reality by those models is much greater than the claim of classical mechanics ever could be. Quantum mechanics is based in uncertainty, in that it offers only probabilistic certainties. While it can assert no single thing with certainty, it asserts everything with probability; "the mathematical apparatus of the new theory provides means of assigning, for the same or any later instant of time, a fully determined *statistical distribution* to *every* variable, that is, an indication of the fraction of cases it will be found at this or that value, within this or that small interval (which is also called probability)" (Schrödinger 325). The statistical methods depend upon and derive from a limit placed upon the knowable by these mathematical formulations. The limit is most clearly stated in the Heisenberg uncertainty principle: the variables defined by this relation exist in conjugate pairs, wherein an increase in knowledge ascertained about one will decrease the available knowledge about the other. One cannot know both the exact momentum and position of a particle at the same time. The more one knows about the position the less one can know about the momentum, and vice versa. A statistical model is necessary because, in reality, says quantum mechanics, it is simply not possible to have sharp values, to know the values of all operators with an arbitrary degree of precision.

Quantum mechanics contains, and relies heavily upon, a measure of its own certainties and uncertainties, called the ψ-function, or wave function, "an imagined entity that images the blurring of all variables at every moment just as clearly and faithfully as the classical model does its sharp numerical values" (Schrödinger 327). Despite being a picture of blurriness, the wave function is nonetheless understood to be a complete picture of the situation, of the state of all the variables in question. The blur is understood to reside not in the model, but in reality itself—as in the "difference between a shaky or out-of-focus photograph and a snapshot of clouds and fog banks" (328). Quantum mechanics sees itself as a perfectly clear photograph of a very cloudy landscape.

Schrödinger's essay is written in response to an essay by Albert Einstein, Boris Podolsky, and Nathan Rosen, titled "Can Quantum-Mechanical Description of Physical Reality

Be Considered Complete?" This is the essay that first posed the challenge to quantum mechanics now known as quantum entanglement. While Schrödinger is the one to propose the term "entanglement," Einstein, Podolsky, and Rosen describe the paradox that defines it. The EPR paradox, as it is now known, violates the uncertainty principle by inventing a scenario in which one can, mathematically at least, know more than one ought to be able to know. The specific situation concerns what happens when two systems whose wave functions are known interact to form one system and then separate again. When the systems separate, regardless of how far apart they are, they seem to remain connected. Interrogate one and it will give you an answer about the other. Interrogate the other and its answer will change. This connection is referred to as entanglement.

Schrödinger uses the example of a schoolboy taking an exam to explain the situation of entanglement. He describes two systems, each defined by only two variables: a large system of Q and P, and a small system of q and p. Between these two systems an entanglement can arise that will allow us to know the relationship between the related variables in the separate systems, Q and q, and P and p. The systems are examined separately, in no determined order. One can procure a measurement of either Q or P from the large system before or after one questions the small system, but "My small system, like a schoolboy under examination, *cannot possibly know* whether I have done this [question the large system] or for which questions, or whether and for which I intend to do it later" (335). The schoolboy is honest, he hasn't snuck in to listen to the professor question the pupil before him, he hasn't had access to the test in advance. He encounters the questions anew at every examination.

The schoolboy in question always does well at the start of the test; "From arbitrary many pretrials I know that the pupil will correctly answer the first question that I put to him" (335). Whichever one comes first, the p question or the q question, the student will answer it correctly; "From that it follows that in every case he *knows* the answer to both questions" (335). This moment where Schrödinger attributes an apparently obvious inner knowledge to the small system is where he departs from the probabilistic interpretation of quantum mechanics. The schoolboy's knowledge, what he later calls "the 'memory technique' of the pupil" stands for a complete stable picture of reality, where the universe holds in waiting exact values for all variables (336). It pairs an image of subjective interiority, the student who knows, with a concept of objective exteriority, to generate a version of reality that "holds a quite definite answer ... in readiness" (335). The universe waits, like a wise virgin, with the lamp of an answer lit for the questions of the physicist.

The student of the small system nevertheless seems to be rather bad at taking tests. He answers the first question correctly, but never the second. "That the answering of the first question, that it pleases me to put to him, so tires or confuses the pupil that his further answers are worthless" doesn't change Schrödinger's conclusion that the student knows both the answers (335). After all, if you ask the questions in the reverse order, the student will answer the other question correctly. "No school principle would judge otherwise, if this situation repeated itself with thousands of pupils of similar provenance, however much he might wonder *what* makes all the scholars so dimwitted or obstinate after the answering of the first question"—he would never wonder *that* the scholars are capable of answering the second question (335). Nor would he, the school principal, think that his own prior or subsequent actions determine the student's success on the first question, "He would not come to think that his, the teacher's, consulting a textbook first suggests to the pupil the correct answer, or even, in the cases when the teacher chooses to consult it only after the ensuing answers by the pupil, that the pupil's answer has changed the text of the notebook in the pupil's favor" (335). Consulting the textbook or notebook here stands for questioning the other system, the P and Q system. The answers in the textbook should exist quite independently of the student's knowledge. Of course, they don't, neither in quantum mechanics nor the educational environment. The student's knowledge does not exist independently of the textbook, or the systems of instruction and examination by which the teacher transmits and extracts knowledge from the text, and from her own education, her own embeddedness in a system of instruction and examination, a knowledge that passes both to and from the student, who will go on to determine the subsequent fields of available knowledge and write the next generation of textbooks. The teacher consulting the textbook informs the student's answer: how could it not?

What Schrödinger doesn't consider is the solution that Niels Bohr proposes in his own response to the Einstein, Podolsky, and Rosen paper, published the month before the paper we are considering. Schrödinger fails to imagine that the exam itself determines the answers of the student. Bohr's paper doesn't provide colorful illustrations like Schrödinger's, and he might object to this scenario on more levels than one, but if we set up the same example for Bohr's theory, his student would be a real slacker. The student hasn't studied at all, he never comes to class, and he doesn't know anything in advance of the test. The test becomes the moment of instruction that produces its own results. Trapped in a bubble of transference and countertransference the teacher and the student co-create the conditions in which it is possible for the student to correctly answer the first question and fail to answer the second. Both the student's knowledge and the student's resistance are created by the test; in the practice of testing the answers are determined, on both ends of the equation. This is the answer to the problem of quantum entanglement that is currently held to be true: the observer co-creates the reality she observes by testing it. The universe does not lie in wait for discovery by science. Quantum mechanics turns out to be remarkably psychoanalytic. On a sub-atomic scale, there is no reality testing in which reality precedes the test; anything you might call reality changes every time you poke it.

The Einstein, Podolsky and Rosen article begins by stating the criterion of correctness for their theory in terms of a philosophical question about the nature of reality and the construction of reality as an object of inquiry, "Any serious consideration of a physical theory must take into account the distinction between the objective reality, which is independent of any theory, and the physical concepts with which the theory operates. These concepts are intended to correspond with the objective reality, and by means of these concepts we picture this reality to ourselves" (777). While there is a necessary distinction between reality and the concepts we use to describe it, there must nevertheless also be a correspondence. Reality exists first; concepts are only useful to the extent that they describe it. Schrödinger shares with Einstein, Podolsky, and Rosen the position that an objective reality exists that is independent of any theory. When Niels Bohr argues the contrary position, that reality does not pre-exist the investigations of the physicist or the philosopher in any stable sense, he aligns himself with the social constructivist approach in the humanities. Just as Roland Barthes argues that the reader participates in the creation of the text as she reads it, Bohr maintains that the observer co-creates the reality she is investigating with her experiments.

While the Einstein, Podolsky, and Rosen paper, published in the American journal *Physical Review*, in March of 1935, is written in a clear, swift, scientific style, that uses equations for words whenever possible, and Bohr's reply, of the same title, printed in the same journal in October of that year, is longer and more pedantic, but similarly pitched, the tone of Schrödinger's response is rather hard to grasp. John Trimmer, who translated Schrödinger's text for the *Proceedings of the American Philosophical Society* in 1980, describes his attempt to convey its "semi-conversational, at times slightly sardonic flavor" (232). This is perhaps an understatement. Schrödinger's text is long, wordy, and sarcastic; with rather few equations, but a great many descriptive figures, like the famous cat, and the pupil that here concerns us. *Die Naturwissenschaften*, the initial vehicle of the text, was not aimed at a disciplinary in-group, but at a broader group of scientifically literate readers. Arnold Berliner, the founding editor, in the first issue, launched his journal with the following task: "inform all those working in scientific fields, either researchers or teachers, about what interested them outside their own fields" (qtd. in Thatje 1106). Already the teacher is present, from the beginning, in the imagined audience, exploring fields of knowledge that escape their individual domains.

Peter Fenves, in his recent article on "The Problem of Popularization in Benjamin, Schrödinger, and Heidegger circa 1935" connects this question of readership, of writing science or philosophy for the non-specialists, to the concept of "Verschränkung"—which Schrödinger himself translates as "entanglement" as in "quantum entanglement." It is significant for Fenves that the word "Verschränkung" appears at key moments in Heidegger's *Introduction to Metaphysics* and in Benjamin's "Work of Art in the Age of Mechanical Reproduction" both texts that contain a theory of popularization while themselves being ambiguously, potentially, popular works. Heidegger's title, describing the book as an *Introduction*, positions him alongside Berliner and *Die Naturwissenschaften*, according to Fenves; "The title suggests that the professor seeks to produce a report that would lead his auditors into his field of expertise, thus achieving an intra-scholastic popularization" (122). Heidegger denies this aim, not by denying the popular possibilities of his lectures, but rather by denying metaphysics itself access to the language of popularization.

The *Introduction to Metaphysics* is not introductory, it fails to participate in the project Berliner outlines for *Die Naturwissenschaften* because that project would require a method of communication, illumination by examples, to which Being should not be submitted. Speaking outside one's discipline requires figures, images, examples, like Schrödinger's cat. Yet examples, as a rhetorical structure, fail to encompass the fundamental focus of metaphysics, according to Heidegger. Being is not a word like any other, because it names what it is (what is): "we distort it fundamentally if we try to illuminate it by examples—precisely because every example in this case manifests not too much, as one might say, but always too little" (*Introduction* 62). The ways in which Being exceeds the figural logics of language are, for Heidegger, what make examples so dangerous. Examples encourage the misreading of Being—either reading in the wrong way, or reading by the wrong people, depending on how charitable you want to be to Heidegger—and that misreading generates a dangerous entanglement of philosophy and politics. According to Fenves's reading of Heidegger, this particular form of entanglement, as it marks the popularization of philosophy, is another name for the misreading and misappropriation of Heidegger's philosophy by the National Socialist movement.

Fenves connects the "entanglement of being, unconcealment, and seeming," that flashes on the screen for a brief moment in the fourth and final section of the *Introduction to Metaphysics*, to the murkiness, the blurriness that Heidegger sees muddying the waters of the Nazi movement. In Heidegger's posthumous essay defending his professional and philosophical engagements with the Third Reich, he presents National Socialism as a failed popularization of philosophy in general and Nietzsche's work in particular. According to Heidegger, this popularization generated an entanglement that he hoped to sort out by assuming the position of Rector of the University of Frieburg and joining the Nazi party. As Rector, he claims in the conditional past, he would have been able to alter the misguided paths of both the university and the party and disentangle the two. Of course he could not and did not. Even as a doubtful defense posed decades after the horrors of Nazi policy made themselves manifest in the Second World

War, Heidegger's posthumous disentanglement hypothesis is conceptually flawed.

It would seem, if we follow Heidegger's logic back to quantum mechanics, that *Verschränkung*, entanglement, belongs to the blurred variables of the Heisenberg uncertainty principle. Heidegger and Schrödinger would both be trying to disentangle the variables, to separate political science from pure philosophy, "join[ing] in secret in order to gradually purify and moderate the 'movement' that had come to power" as Heidegger claims he wished to do ("Self-Assertion" 486). In fact entanglement, in the quantum mechanical sense, refers not to the blurry murky statistical model of reality, but to a particular moment when reality presents itself with a sudden and inexplicable clarity. Entanglement marks a gap in the wave function, a case where variables that should be blurry become sharp, where that which should be unknowable is known. If entanglement is predicated on a revelation of correlation, disentanglement is not a clarification but a process of obfuscation and erasure. The theory of quantum entanglement derives from the observation that two systems which interact to the extent that they can be described as entangled cannot be fundamentally disentangled. Entanglement occurs in situations in which two systems, two sets of subatomic particles, philosophy and political science, national socialism and the university, particle physics and the military industrial complex, come together and then separate. Although in principle the systems are non-communicating entities with distinct probability distributions after they separate, knowledge of the interaction will grant us knowledge of both systems after the separation. Testing one component of one system will gain you knowledge about the other, Heidegger will tell us something about the Fürher and vice versa, even though, as components of separate systems, the university and the state, philosophy and politics, they shouldn't.

The clarification proposed in the Schrödinger's cat paradox likewise points us toward National Socialism. The cat paradox imagines a "diabolical device" in order to point out the absurdities of quantum ambiguities. It involves a cat in a steel box who may or may not be dead, depending on the possibility of atomic decay. If the atom decays, the "diabolical device" kills the cat; if it does not, the cat lives. Yet for the equations to hold true, the cat must be dead and not dead simultaneously. The method of the cat's possible death, "a small flask of hydrocyanic acid," is the chemical name for ZyklonB (Schrödinger 328). The example forces the probabilistic certainties of quantum mechanics into the undeniable certainties of the death chambers. Here the locus of certainty and uncertainty, clarity and blurriness has flipped: clarification leads to the death chambers rather than away from them, as Heidegger would have it.

Schrödinger's essay is positioned precariously athwart a set of political variables. The author of small cat death chambers cites the exiled Einstein in a footnote, a dangerous political move to make in a German publication, three months after its founding editor had been dismissed under Nazi racial policies. In that footnote Schrödinger states that he is uncertain if he has made a "Referat" or a "Generalbeichte": a lecture or a public confession. In translation the footnote reads, "A. Einstein, B. Podolsky, and N. Rosen, *Phys. Rev.* 47: 777 (1935). The appearance of this work motivated the present—shall I say lecture or general confession?" (334). We can say that the double genre of the paper, as lecture and confession, as technical and popular writing, is the result of an entanglement of the Schrödinger system with the Einstein system, or the Schrödinger system with the National Socialist system, but this would be a return to our earlier misreading of entanglement as confusion. It would be better to say that the two genres of this paper are two particles, acting unexpectedly in concert, revealing a previous entanglement. The two genres, technical and popular writing, are the offspring of two disciplines, which were previously one, physics and philosophy, or more broadly speaking, the sciences and the humanities. We can trace the division simply through the question of style. Victorian scientific literature was, by and large, accessible to the reading public, as Gillian Beer comments in *Darwin's Plots*, scientists and other educated readers and writers, "shared a literary, non-mathematical discourse which was readily available to readers without a scientific training" (4). By the mid-20th century, the broader legibility of scientific discourse had all but vanished. Scientists were being educated into an increasingly specific, complex, and hermetic set of discourses that they used to communicate and perform increasingly specialized research. In many ways the humanities responded in kind, producing its own discursive tools of increasing complexity and difficulty. The modernist linguistic constructs of James Joyce and Gertrude Stein are contemporary with and complementary to the quantum mechanics theories of Max Plank and Albert Einstein: both mark the beginning of a departure from the shared space of literary and scientific language. By the post-war era, when the prominence of physics was firmly established in the sciences by the results of the Manhattan Project, the two disciplines were discursively and culturally strangers. The consequences of the Manhattan Project are in many ways the results of, as well a continuing force behind this estrangement. The construction and deployment of the atomic bomb belongs, historically, to a pattern of scientific thought that is already structurally separate from literature and philosophy. The atomic bomb is the child of science's second marriage, with politics, after its divorce from philosophy.

The foregoing discussion of the cultural split between the sciences and humanities aims to suggest that we can read Heidegger's famed difficulty, or even Kant's, as a movement similar to the modernist difficulty of Joyce and Stein, a movement away from, but impelled by the same momentum as the increasing technical difficulty of scientific language. It also suggests that we can read the generic ambiguity of Schrödinger's paper as an opposite movement, as the double sign of a former union and a desire to return.

Schrödinger is uncertain, he writes in the footnote, if he is giving a lecture or making a general confession. Explicitly, he is giving a lecture about physics, to either a specialist or a generalist audience. Implicitly he is confessing his desire for a general audience, in the form of his writing, a desire for an audience that exceeds the genre specificity of scientific prose, a specificity that would have been less present during his training, but was now becoming more and more evident. This desire encourages him to use examples which, Heidegger would say, permits the possibility of a dangerous misreading, perhaps even, we could say, the (mis)reading of quantum physics that results in the Manhattan Project. Yet if we are to follow through with the negation of Heidegger's entanglement hypothesis, we must say the reverse, that it is not the examples that miss the point and encourage dangerous misreading, but the lack of examples, the lack of a shared popular understanding of scientific knowledge in the larger discourse that encourages the production and use of atomic weapons in the Second World War, just as the structural role of obscurity, the extra-linguistic excess of Being in Heidegger's philosophy permits both its adoption by the Nazi party and his later disavowal of that adoption as a misreading.

Schrödinger is additionally confessing, on a more explicit level, to a disciplinary solidarity with Einstein, established in the citation, with a set of potential political consequences. In this, he is confessing to a doubt he shares with Einstein, a doubt about the fundamental picture of reality painted by quantum mechanics. Both the cat paradox and the figure of the student under examination are images of this doubt. Schrödinger's doubt and the split between the sciences and the humanities are symptoms of a common cause, which we might call, for the sake of this essay, a knowledge crisis.

Let us imagine that the student in Schrödinger's paper is being tested on the Heisenberg uncertainty principle. The first question asks the student to provide his location. The second asks him his momentum. If he can answer the first question accurately, he should not be able to answer the second. That is to say if the correct answer to the first question is "221B Baker St, Marylebone, London NW1 6XE, UK" the correct answer to the second question, according to the Heisenberg text book, is "I don't know, not sure, can't really tell you," or rather, "The knowledge in question cannot be obtained, it does not exist." An increase in knowledge about location decreases the available knowledge about momentum, and vice versa. The right answer, according to the principle, is to state the lack of available knowledge. The wrong answer would be 42 $kg \cdot m \cdot s^{-1}$, or $3.7x10^{-9}h/2\pi$, or any exact value. The wrong answer to the second question indicates that the student has more knowledge than she should. The failure in the test, that which "makes all the scholars so dimwitted or obstinate after the answering of the first question," is not a lack, but an excess of knowledge. The student fails because she knows too much, more than the teacher. This is the specific failure of entanglement, as proposed in the EPR paradox. This failure in excess offers certainty—the student, the system, nature itself, has solid stable pre-determined values that it holds in waiting for the test of the experimental scientist. Yet it also offers uncertainty—the mathematical models that we imagine to be exhaustive are limited, and possible knowledge is not; we are Eve in the garden before the fall. We have not yet constructed a complete picture of reality, we are asking the wrong questions.

What Schrödinger doubts is the limit set on the knowable by a quantum mechanical model of reality. He doubts that the equations of quantum mechanics, a model that he helped to construct, are adequate to the task of describing reality. This doubt is conservative in that it returns to the classroom for a space of certainty, for tests with right and wrong answers, examinations that one can pass or fail, knowledge that pre-exists the test and yields results when tested. Yet this doubt is radical in that it undermines the very structure upon which it is built. It reminds us, as Avital Ronell does in *The Test Drive*, that "the very structure of testing tends to overtake the certainty that it establishes when obeying the call of open finitude" (5). Schrödinger's confession tests its own tests, the grounds of its profession. In suggesting that quantum mechanics is an incomplete theory, it suggests that the test, the experiment, the probabilistic method of generating certainties, is designed to create and enforce a lack of knowledge. Our methods of testing may simply confirm, with great accuracy, our fundamental ignorance. The test, in this instance, has become the figure for, and the mechanism of knowledge in crisis. The crisis is manifest in both the theories and disciplinary practices of philosophy and physics in the mid-twentieth century, and in their disparate unions with the politics of war. In our contemporary climate of political division the test can be reactivated to engage the current crisis. We are already testing the fundamental structures of our political reality, our consensus structure, our institutions, our norms and common ground. Yet our most basic patterns of engagement may be predicated on an inadequate set of assumptions. We should re-calibrate our sensors and re-word our questions. We should be looking for other variables.

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