Preface

All great discoveries in experimental physics have been due to the intuition of men who made free use of models, which were for them not products of the imagination but representatives of real things.

Max Born (1953)

Victor J. Stenger

Atoms and the Void

Most people would agree that science must tell us something about reality. However, no one has stated what exactly that may be. Scientists do not speak with one mind on the matter. They, and the philosophers who study science, have not reached anything approaching consensus on the nature of reality revealed by science, or even if any has been revealed. Still, despite this collective uncertainty, something must be out there in the real world. And, based on its track record, science is still the best tool we have at our disposal to help us find it.

Since the seventeenth century, science has occupied first place among the various approaches that humans have taken in their attempts to understand and control their environment. This special status did not come about as the consequence of a jeweled crown being placed on its head by some higher authority. Rather, science proved itself by results. Its instruments have greatly extended the range of vision provided by the human senses, and the theories of science have profoundly altered the way humanity thinks about itself and its place in the overall scheme of things.

Observation and theory constrained by an uncompromising methodology have worked together to present us with a picture of a universe beyond the imagining of the most talented poet or pious mystic. No other human intellectual or creative endeavor, whether philosophy, theology, art, or religious experience, from East or West, has come close to fantasizing the universe revealed by modern physics and astronomy. Reality is out there telling us that this is the way it is, whether we like it or not, and that reality is far beyond our simple, earthbound imaginations.

In recent years, the privileged position for science has been challenged. Some sociologists and other scholars who have examined science within a cultural context have concluded that statements made within Western science are simply narratives that have no more claim on the truth than the myths of any other culture. So far they have convinced no one but themselves.

Science is not fiction. Although it involves creativity, it is not the sole product of unbridled imagination. Scientists build equipment and mathematical theories, gather and analyze data, and come to an always-tentative consensus on what should be added to or subtracted from the library of scientific knowledge. That library is then utilized by technologists to build the many devices that mark the dramatic difference between the lives of humans today and those of the not-too-distant past.

To be sure, much imagination went into the development of the computer that sits on my desk. But that imagination was forced to act within a framework of constraints such as energy conservation and gravity. These constraints are codified as the "laws" of physics. Surely they represent some aspect of reality and are not pure fantasy.

Scientists themselves, including great numbers of non-Western persuasion, continue to maintain confidence in the exceptional power and value of their trade. They are sure they are dealing with reality, and most people outside of a few departments in academia agree. But, we must still ask, what is the reality that scientists are uncovering?

In this book I suggest that the underlying reality being accessed by the instruments of science is far simpler than most people, including many scientists and philosophers, realize. The portion of reality that responds to the probing of scientific experiment and theory is not terribly mysterious. For those portions remaining unresponsive pending further discovery, we have no basis to believe that they fall outside the naturalist tradition that has developed over millennia. No one need think, after this time, that any phenomena currently lacking full scientific explanation can only be revealed by nonscientific or supernatural means.

Based on all we know today, the complete library of data from across the full spectrum of the sciences is fully consistent with a surprisingly simple model: the natural universe is composed, at the elementary level, of localized material bodies that interact by colliding with one another. All these bodies move around in an otherwise empty void. No continuous, etheric medium, material or immaterial, need be postulated to occupy the space between bodies. Applying an insight more ancient than Plato and Aristotle, but continually ignored because of human propensities to wish otherwise, *atoms and the void* are sufficient to account for observations with the human eye and the most powerful telescopes, microscopes, or particle accelerators of today.

The four-dimensional space-time framework introduced by Einstein and Minkowski, along with the associated rules of relativity and all the rest of physics, are adequate to describe the motion of these primal bodies. Furthermore, we find that the great foundational "laws" of physics—the principles of energy, linear momentum, and angular momentum conservation—are not rules imposed on the universe from outside. Rather they represent physicists' way of theoretically describing the high degree of symmetry and simplicity that the universe, on the whole, exhibits to their instruments.

Four centuries ago, Galileo observed that an object falls with an acceleration that is independent of its mass. We find that the same is true when the experiment is done today (with the usual caveats that we neglect air friction), and we measure the same acceleration of gravity he did. When we look with our telescopes at the farthest galaxies, where the light left billions of years ago, we find that the properties of that light, such as the relative positions of spectral lines, are exactly the same as we observe in the laboratory today.

The fact that the same behavior is found over such an enormous time scale implies that the basic principles of physics do not change over time. No moment, what the Greeks called *kairos* and philosopher Martin Heidegger translated to the German as *augenblick*, stands apart from any other (despite the recent millennial fever). When we proceed to incorporate this fact in our theoretical descriptions, lo and behold we find that energy is conserved. That is, the total energy of any isolated system within the universe is a constant. Energy conservation is simply another way of saying that the universe exhibits no special moment in time.

Galaxies are distant in space as well as time; some are billions of light years away. The fact that the same physical phenomena are observed at all distances in space tells us that the principles of physics are the same at all places. No special position in space can be found where the physics is different. This is what Copernicus discovered when he realized that the earth was not absolutely at rest with the rest of the universe circling about it. When the absence of any special place in space is incorporated into our theoretical descriptions, we find that the physical quantity of momentum is conserved. That is, the total momentum of any isolated system within the universe is a constant. And so, momentum conservation is simply another way of saying that no special place in space exists.

When we look in several directions with our telescopes, we find again that the basic behavioral patterns of the observed light are the same. This absence of any special direction in space is represented in our theories as conservation of *angular momentum*. That is, the total angular momentum of any isolated system within the universe is a constant. Angular momentum conservation is simply another way of saying that the universe exhibits no special orientation in space.

These conservation "laws" are global, applying throughout our universe. Extending rotational symmetry to the full four dimensions of space-time, the principles of Einstein's special theory of relativity join the conservation principles already mentioned. In other words, the most fundamental notions of physics hardly need explanation. Any other form of these laws would be so astounding as to force us to look for some more complex explanation. They eloquently testify to the lack of design to the universe.

While the idea that many of the most important principles of physics follow from space-time symmetries may not strike a familiar chord, this connection has been known for a century or more. You will find it described in advanced physics textbooks in both classical and quantum mechanics. So my assertion represents nothing new, merely a public exposition of well-established physics. Indeed, nothing I will say in these pages should be taken as a proposal to change a single fact or equation in the existing body of physics—or any other science for that matter. I am merely reporting what that science seems to be telling us about reality.

The model of reality I propose is basically the one strongly implied by modern particle physics theory, when the esoteric mathematics of that field is recast in the admittedly less precise medium of words and images. This model cannot be proved correct by any process of deductive logic or mathematics. It is probably not verifiable by additional observations or experiments beyond what has already been done, although more experiments will yield more details and could, in principle, falsify the picture. Nevertheless, the proposed model is based on observation and experimental data, and the theories that currently describe all currently existing data without anomaly. The primary alternative models of reality are likewise not capable of being proved by logic, but I will argue that they are less reasonable, less rational, and less convincing.

Most physicists will object that only the empirically testable merits our consideration. I will not adopt that view, since it leaves us with nothing we can then say about the nature of the reality behind bald statements of fact about observations. I believe we have every right to talk about non-testable ideas, so long as we do so in a logically consistent (that is, non-self-contradictory) fashion that does not disagree with the data. And, criteria other than testability must be available to allow us to make a rational choice among alternatives and make our speculations worthwhile.

The reader will not be asked to believe the proposed picture on the basis of the author's or any more famous physicist's authority. The model I will present is simple, economical, and possibly even useful, and these are rational criteria for making a choice. At the very least, I hope to demonstrate that nothing we currently know from our best sources of knowledge requires anyone to buy into one or more of the many extravagant claims that are made by those who would try to use science to promote their own particular mystical or supernatural worldview. Since these promoters introduce extraneous elements of reality not required by the data, their proposals fail the test of parsimony. It then follows that they have the burden of proving their schemes, not I the burden of disproving them.

Of course, the universe we see with eyes and instruments is not "simple" by our normal understanding of the term. The details we observe are very complex, with many layers of structure and other physical laws besides conservation principles that follow from the global symmetries of the universe. However, I will try to show that these complex structures and laws can still be grossly understood in surprisingly simple terms, where the details are unimportant. I will describe a scenario, consistent with current knowledge, where complex order arises from the spontaneous, that is, uncaused and accidental, breaking of symmetries that themselves were uncaused.

Just as the structure of living organisms is the result of spontaneous events acting within the global constraints of energy conservation and other limiting factors like gravity and friction, so, too, could the structural properties of elementary matter have evolved spontaneously in the early universe. At least nothing we currently know rules this out. In the proposed scenario, what emerged in terms of particle properties and force laws during the early evolution of the universe was not pre-determined by either natural or supernatural law. Rather, it arose by chance. Start the universe up again and it will turn out different.Thus, much of the detailed structure of the universe, so important to us as earthbound humans, is not of great importance to our basic understanding of reality. This structure could be wildly different, and that basic understanding would be unchanged.

I will discuss the possibility of other universes besides our own. These might be imagined to have different structures, different laws. While no one can demonstrate that other universes exist, current cosmological theories allow, and even suggest, that they do. Again, no known principle rules them out. To assume ours is the only universe is to take the narrow view of humans before Copernicus that the earth is the only world beneath the heavens. It seems very likely that the sum of reality includes a vastness of possibilities in which our universe is but a speck, even as our earth is a but speck within that universe. The so-called anthropic coincidences, in which our universe appears, to some, incredibly fine-tuned for the formation of carbon-based life, are readily accounted for in a universe of universes. And those who think these coincidences provide evidence for some special design, with humans in mind, exhibit the same lack of imagination as those who once thought that only one world existed and all else revolved about it.

Moving from the vast to the tiny, one place where a model of a reality containing only localized bodies may be reasonably questioned is at the level of quantum phenomena. Quantum events have been widely interpreted as providing a basis for any number of strange or even mystical and holistic effects.

For seventy years, the Copenhagen interpretation of quantum mechanics has presided as the consensus view of physics, a position that has only recently begun to erode. The way in which the observer and observed are intertwined in this interpretation has suggested to some that human consciousness has a controlling role in determining material behavior. I discussed this issue thoroughly in my previous book, *The Unconscious Quantum: Metaphysics in Modern Physics and Cosmology*(Stenger 1995), and have tried not to be too repetitive here. In some ways, this is a sequel to that book; however, *Timeless Reality* should be self-contained.

As I described in some detail in *The Unconscious Quantum*, and will only briefly summarize here, David Bohm postulated the existence of a mysterious holistic field that acts instantaneously throughout the universe to bring everything together into one irreducible whole. Bohm's model could not be more diametrically opposed to the one I will describe here. I will not disprove the Bohm model, but argue against it on the basis of parsimony.

The *many worlds interpretation*, which envisages our universe as an array of parallel worlds that exist in ghostly connection to one another, is less in conflict with the ideas I will present. Many *worlds* is not to be confused with the many *universes,* mentioned above, that go their own separate ways, presumably never coming into contact after they are formed. Many worlds might be found in each of many universes. However, the many worlds interpretation is not required in the proposed scheme and other alternative views will be presented. It may be possible to retain the ideas of the many worlds interpretation within in single world.

Other interpretations of quantum mechanics exist, but none have the dramatic implications of the big three: Copenhagen, Bohmian, and many worlds. No consensus has developed as to which, if any, is to be preferred, though each has a list of distinguished supporters. As we will see, there are many ways to skin Schrödinger's cat.

All attempts to come to grips with the observed outcomes of a wide range of quantum experiments, by applying familiar notions based on Newtonian classical physics, have conclusively failed. Still, classical physics remains highly successful when carefully applied to its own still very wide domain, which encompasses most familiar physical phenomena. Since common sense is based on our normal experience of these phenomena, something of common sense must give in trying to understand the quantum world.

One commonsense notion that may be expendable is that time changes in only one direction. As we will see, quantum events proceed equally well in either time direction, that is, they appear to be “tenseless.” This is what I mean in the title: *Timeless Reality*. By allowing time to change in either direction, many of the most puzzling features of quantum mechanics can be explained within the framework of a reality of atoms and the void.

It may be a matter of taste whether you find timeless quanta more palatable than conscious quanta, holistic fields, or ghost worlds. In any case, I am not proposing an alternative interpretation of quantum mechanics, and various ideas from the many proposals in the literature may still be necessary to provide a complete picture. I merely urge that time symmetry be considered part of any interpretive scheme. As we will see, it provides for a particularly simple and elegant model of reality.

I am not the first to suggest that time symmetry might help explain some of the interpretive problems of quantum mechanics. In fact, this has been long recognized but discarded because of the implied time-travel paradoxes. I will show, again not originally, that the time-travel paradoxes do not exist in the quantum world. I feel that the possibility of time-reversal has been widely neglected for the wrong reason—a deep prejudice that time can only change from past to future. Evidence for this cannot be found in physics. The only justification for a belief in directed time is human experience, and human experience once said that the world was flat.

I ask you to open your mind to the possibility that time can also operate from future to past. The symmetry between past and future is consistent with all known physical theories, and, furthermore, is strongly suggested by quantum phenomena themselves. The indisputable asymmetry of time in human experience arises, as Ludwig Boltzmann proposed over a century ago, from the fact that macroscopic phenomena involve so many bodies that certain events are simply far more likely to happen in one direction rather than the reverse. Thus, aging is more likely than growing younger. We do not see a dead man rising, not because it is impossible but because it is so highly unlikely. But time asymmetry is no more fundamental than the left-right asymmetry of the face you see in the mirror—a simple matter of chance.

Classical physics is well-known to be time symmetric. Although the second law of thermodynamics is asymmetric by its very nature, it simply codifies the observed fact of everyday life that many macroscopic physical processes seem to be irreversible. However, the second law does not demand that they be so. In fact, every physical process is, in principle, reversible. Many simply have a low probability of happening in reverse. As Boltzmann showed, the second law amounts to a definition of the arrow of time.

Time symmetry is commonly observed in chemistry, where all individual chemical reactions can occur in either direction. The same is true in nuclear and elementary particle physics. In only a few very rare particle processes do we find the probability for one time direction very different from the other, and even then to just one part in a thousand. While this exception requires us to strictly reverse the spatial as well as time axes and change particles to antiparticles when we reverse the time direction, this will not negate our conclusions about time symmetry. In fact, these small complications will give us an even deeper understanding of the principles involved, which are that natural, global symmetries lead to the great conservation laws of physics.

With all this taken into account, we can state that the microscopic world is quite time symmetric. The equations that describe phenomena at that level operate equally well in either time direction. But, more importantly, the experiments themselves seem to be telling us not to make an artificial distinction between past and future. Those quantum phenomena that strike most people as weird are precisely the ones where the future seems to have some effect on the past. Weirdness results only when we insist on maintaining the familiar arrow of time and defining as weird anything that is not familiar.

Experiments demonstrate unequivocally that quantum phenomena are *contextual.* That is, the results one obtains from a measurement depend on the precise experimental setup. When that setup is changed, the results of the experiment generally change. This may not sound surprising, but what people do find surprising is that the results change even in cases where common sense would deny that any change was possible without a superluminal signal.

In Einstein's theory of relativity, and modern relativistic quantum field theory, no physical body or signal can travel faster than the speed of light. In experiments over the past three decades, two parts of a quantum system well-separated in space have been found to remain correlated with one another even after any signal between them would have to travel faster than the speed of light. While some correlation is expected classically, after this correlation is subtracted an additional connection remains that many authors have labelled mysterious—even mystical. While these observations are exactly as predicted by quantum theory, they seem to imply an insepa-rability of quantum states over spatial distances that cannot be connected by any known physical means.

As has been known for years, time reversibility can be used to help explain these experiments. We will see that their puzzling results can be understood, without mystical or holistic processes, by the simple expedient of viewing the experiment in the reverse time direction. Filming the experiment and viewing it by running a film backwards through the projector, we can see that no superluminal signalling takes place.

Let us consider another example that leaves people scratching their heads: A photon (particle of light) that left a galaxy hundreds of millions of years ago may be bent one way or another around an intervening black hole. Suppose the photon arrives on earth today, and triggers one of two small photon detectors, separated in space, that tell us which path the photon took.

A special arrangement of mirrors can be installed in the apparatus so that the light beams from both paths around the black hole are brought together and made to constructively interfere in the direction of one detector and destructively interfere in the direction of the other. The first detector then always registers a hit and the other registers none. This is as expected from the wave theory of light.

Now, the puzzle is this: the decision whether or not to include the mirrors is made today. Somehow it reaches back to the time of the dinosaurs to tell the photon whether to pass one side of the black hole, like a good particle should, or pass both sides and interfere, like a good wave should.

While this particular astronomical experiment has not, to my knowledge, actually been conducted, a large class of (much) smaller-scale laboratory experiments imply this result. These experiments, I must continually emphasize, give results that agree precisely with the predictions of quantum mechanics, a theory that has remained basically unchanged for almost seventy years. So any discussions and disputes I may report are strictly over the philosophical or metaphysical interpretation of the observations, not any inconsistency with calculations of the theory.

In the traditional methods of classical mechanics, a system is initially prepared in some state and equations of motion are then used to predict the final state that will then be observed in some detection apparatus. However, quantum mechanics does not proceed in this manner. In the most commonly applied procedure, the initial state of the system is defined by a quantity called the **wave function**. This wave function evolves with time in a manner specified by the **time-dependent Schrödinger equation** to give the state at some later time. The wave function, however, does not allow one to predict the exact outcome of a measurement but only the statistical distribution of an ensemble of similar measurements.

Although not exhibiting any preference for one time direction or another, this series of operations still seems to imply a time-directed, causal process from initial to final state quite analogous to Newtonian physics. By removing our classical blinkers, however, we can see that quantum mechanics basically tells us how to calculate the probability for a physical system to go from one state to another. These states may be labelled "initial" and "final" to agree with common usage, but such a designation is arbitrary as far as the calculation is concerned. Nothing in the theory distinguishes between initial and final.

Furthermore, whereas classical physics would predict a single path between the two states, quantum physics allows for many different paths, like the two paths of the photon around the black hole. The interference between these paths leads to many of the special quantum effects that are observed. It is as if all paths actually occur, and what we observe is some combination of them all.

When we try to think in terms of particles following definite paths, however, we run into conceptual difficulties. In our cosmic experiment, for example, the photon somehow has to pass on both sides of the black hole to interfere in our apparatus a hundred million years later. We can arrange our detector to count a single photon at a time, so we can't think of it as two different photons. The same photon must be in two places at once.

The conventional wisdom has held that physicists should not speak of anything they cannot directly measure or test against measurements. So, according to this rule, we are not allowed to regard the photon as following a particular path unless we actually measure it. When we try to do that, however, the interference effect goes away. The party line for many years has been to leave this as it is. The equations give the right answer—what is observed. However, this policy has never provided a satisfactory response to the question of what is "really" happening.

I suggest that at least part of the solution has been there all along in the time symmetry of quantum theory and the apparent backward causality evident in quantum experiments. As long as they remain in a pure quantum state, photons can reach just as far back in time as they can forward, as can electrons and other subatomic particles. These bodies can appear in two or more places at once, because a backward moving particle can turn around and go forward again, passing a different place at the same time it was somewhere else. A particle going one way in time can be accompanied by its antiparticle going backward in time in a single (coherent) state of one particle. Together they constitute the timeless quantum.

Every author must gauge his or her audience and write with that audience in mind. This book, like *The Unconscious Quantum*, is written for a science-literate audience. That is, the reader is not expected to be a scientist or other scholar highly trained in science or the philosophy of science. I write for the much larger large group of generally educated people who enjoy reading about science at the popular and semi-popular level, in books and magazines. They also follow the science media, and are interested in the grand scientific issues of the day, especially as they interact with other areas of thought in philosophy, religion, and culture. Scientists and philosophers who may themselves not be experts in these specific issues are also kept in mind as potential readers. Hopefully, the experts will not object too much to what they read, for I have undoubtedly oversimplified in places and provided insufficient caveats.

As we will see, many of the matters being heatedly debated today are ancient, even eternal. They will not be settled by me, any more than they have been settled by the thousands who have discoursed on the nature of reality from the time words were first used as a medium for that discourse. I am not trying to finalize these matters but make some of their latest manifestations more accessible to the reader and to perhaps open up a few neglected lines of thinking for the professional.

I will regard my goal as satisfied if I succeed in slightly deflecting thinking in directions that have not been, in my view, adequately explored. Most philosophical, theological, cultural, and historical discourses implicitly assume directed time. Most models of physical reality implicitly assume the existence of material continua. Most attempts to account for the order of nature have suggested a Platonic reality which theists call God and non-theists call the "theory of everything." I suggest that, based on current knowledge, all of these approaches are at best weakly founded. As I will attempt to show, no basis exists for assuming that the detailed structure of the universe is the product of either logical necessity or supernatural design.

In adopting the medium of a semi-popular but still scholarly book to suggest new ideas, I am catching a ride on a recent trend. For most of the twentieth century, scientific and philosophical discussions were largely confined to the professional journals and a few, highly priced technical monographs of limited circulation and even more limited comprehensibility. In more recent years, biologists Stephen Jay Gould, Richard Dawkins, Francis Crick, and E. O. Wilson have used the medium of the popular book to promote original ideas in that field that differ from the mainstream. In physics and cosmology, Stephen Hawking, Roger Penrose, David Deutsch, Lee Smolin, and many others have done the same. Other fields, such as neuroscience, complexity theory, and artificial intelligence, have seen similar use of this medium to promote new and controversial ideas. The excellent sales by this array of authors testifies to the market for new and challenging thoughts about fundamental issues of life, mind, and the universe. In some cases, the proposed ideas have begun to trickle down into the heavily conservative, formal disciplines in which their authors have usually made substantial contributions.

Of course, the less formal presentations and freer flow of ideas of pop-ular literature force the reader to search for the pony in a huge mountain of horse manure. In the case of the Internet, this mountain is of Everest proportions. But the lesson of the Internet so far seems to be that the shoveling is well worth the effort, once that beautiful pony is found.

I hope that this book will not require a large shovel. In fact, it is the result of many years of spade work on my own part. In the four decades before its publication I have taught physics at every level and participated in research that helped elucidate the properties of almost every type of elementary particle, from strange mesons and charmed quarks to gluons and neutrinos. I have looked for gamma rays and neutrinos from the cosmos whose energies exceed anything yet produced on earth. This was with many collaborators to whom I owe a great debt of gratitude. While not a trained theorist or philosopher, I have also published a few theoretical and philosophical papers.

Over these four decades I have constantly tried to understand and explain the basis of the physical world in simple terms. As much as possible, I have supplemented or replaced the equations and abstract symbols of physics with words and visual concepts. We humans seem not to "understand" an idea until it is expressed in terms of words and pictures although equations can, more compactly and precisely, say the same thing. In this book I present these words and ideas. In a few places, I use a symbol or a simple equation, but these are nothing more than shorthand. For completeness, the endnotes contain a few short derivations so that the mathematical reader can understand somewhat more precisely what I am saying.

A few caveats are also included in the notes, in the interest of accuracy, but these are minimal. Technical terms are boldfaced in the text the first time they appear, or when they haven't appeared for a while, and are defined in the glossary. I have tried to keep the discussion in the main text as complete as possible. In some places, technical aspects of a subject are described in some detail that may make for rough going for those not already familiar with the ideas. If the thread is lost in going through these sections, it should be possible to pick it up again at some point a paragraph or two later. The reader is encouraged to simply plunge ahead in those cases where he or she finds the going rough. The basic ideas are summarized and repeated many times.

I have been helped enormously in this work by the availability of the Internet and its unprecedented communication power. I formed an electronic mail discussion list (avoid-l@hawaii.edu), whose membership at times exceeded fifty, and placed the drafts and figures for this manuscript on a World Wide Web page (http://www.phys.hawaii.edu/vjs/www/void.html). Members of the list could then read the latest drafts and post comments for myself and others to read, all in a completely open fashion. No one was excluded or censored, and the discussion often ranged far and wide.

While not everyone on the list joined in the discussions, I must mention those who have directly helped me prepare the work you see before you by providing comments, suggestions, and corrections: Gary Allan, Perry Bruce, Richard Carrier, Jonathan Colvin, Scott Dalton, Keith Douglas, Ron Ebert, Peter Fimmel, Ron Ebert, Taner Edis, Eric Hardison, Carlton Hindman, Todd Heywood, James Higgo, Jim Humphries, Bill Jefferys, Norm Levitt, Chris Maloney, John H. Mazetier, Jr., David Meieran, Ricardo Aler Mur, Arnold Neumaier, Huw Price, Steven Price, Jorma Raety, Wayne Spencer, Zeno Toffano, Ed Weinmann, Jim Wyman, and David Zachmann. That is not to say that any or all of these individuals subscribe to the views expressed in this book. Indeed, several hold strong opposing views and helped me considerably as friendly but firm devil's advocates. Many thanks to all, and to the many others who also helped by their interest and encouragement. And, as always, I have been advised, supported, and sustained by the wonderful companion of my life, my wife Phylliss, and our two adult offspring, Noelle and Andy.