THE FUTURE OF PHYSICS

Philosophy and science have become estranged.

Hans Reichenbach (1927)

It was perhaps excusable that a revolution in mental attitude should occur once, because after all physics is a young science … but it would certainly be a reproach if such a revolution should ever prove necessary again.

Percy Bridgman (1927)

We are more likely to develop a correct theory of nature from a meaningful theory than from a meaningless one.

David Finkelstein (1991)

The study of the universe will become the major theme in physics in the 21st century.

Nikos Prantzos (1999)

As we learn more about the nature of gravity, especially at the quantum level, we can expect our powers over gravity to grow.

David Darling (2006)

It happened many times in physics that the most profound changes in technology came from fundamental investigations.

Anton Zeilinger (2008)

We need a new discovery.

Mike Lazaridis (2009)

Behind the hills the sun is set to rise into pale blue but on the street the light already has a concrete hue. Walking from the station to another shift I feel bereft. It's a feeling that I never had before. How bright his shining score: 42 of 47 problems solved or turned to new investigations. My mood clouds his brilliance with unwonted gloom. There's tension in the office too as I'm half-waiting for a knock to signal that my life's about to take another turn. Of course it never does while I await it. I turn to my task of tying up loose ends.

It troubles me that the loose end that troubles me the most is physics. This pitches me into new visions of the old divides. It was religion that devised the Inquisitions. Nine centuries of so-called reasons for state terror, less widespread of late. For me the rise of physics symbolizes reason—or at least the opportunity for reason—in our time. Its foundation is philosophy—or so I see it. Could this be why I would choose it for my studies years ago? It's Reichenbach who says, 'The

classical philosophers had a close connection with the science of their times.' He mourns the later loss of understanding between science and philosophy; it might be called a loss of mutual respect. He doesn't say that science is responsible. 'Philosophy,' he says, 'still acts like a stranger toward the gigantic complex of natural science, even to the point of rejecting it.' It's a schism that is like a third divide.

Smolin sounds the call to renew physics by returning to its once-successful practice as math driven by philosophy. He echoes Reichenbach, who says that physics' task is to make statements about reality. But when he's asked to name the big surprise in thirty years of physics theory he says, 'The biggest surprise … is that there have been no surprises.' To me this sounds a tocsin. Could we lose the drive to civilize? That humankind is herdable to scurvy ends runs deep within the tribe. It's an unlikely poet, Ho Chi Minh, who writes that:

> In the mountains, I met the tiger and came out unscathed.
> On the plains, I encountered men, and was thrown into prison.

I see fundamental physics as a bulwark against prison on the plains—Ho's symbol of all fundamentalisms. Like Lazaridis says, it needs renewal. This is my ultimate loose end. As I cast around for what I feel about it, Gilder rallies to my aid. She says that 'Science unfolds in some directions rather than others because of circumstances.' She persuades me we can thank—or blame—the circumstances—characters and plot twists as she puts it—for QM. We might have succored Bohm instead of Bohr; we might by now be looking at a quantum theory that makes sense.

To push this point back earlier than Gilder does: QM comes to us courtesy of physics' love affair with light, which predates Newton's *Opticks*. The love affair is possible because of circumstances that make glass. Some character whom we might see as savage made it long before Sir Isaac uses it to split light into spectrum. Glass, he finds, can bend light's path. Later someone else—another character—discovers that it goes round corners by itself. Marry this to the corpuscle concept and in time QM is born. Could it be that without glass our physics might have advanced further in a different direction? Could we have possessed for years a quantum theory at the level where it actually happens—real small, to coin a whole new meaning for a down-home phrase—a trillion-trillion-fold more miniscule than current subjects of QM? Of course more likely we'd have finished up with nothing of the kind; but physics has its share of might-have-beens.

And, too, science is personal. As Lederman says, tongue in cheek, 'Scientists, more often than not, are people.' To take this one step further, science has its share of what Joanna Russ (with alien perspective) labels yoomin beans. Physics might be better for it if more physicists were seen to wear this tag. Yoomin beans come bundled up with yoomin flailings. Someone who envisions physicists as far

above the fray might think that they would send their big guns out to back the B-T helons. Being yoomin, actually not. Nor are helons swept under the rug; it's more like they were born there. The odds seem good that that's where they will die. But, shades of Poe: They may yet rise again. As Gilder says, it's characters and plot twists, circumstance.

What difference does it make? My missing buddy's question. Well, the physics driving today's economic progress is all electromagnetic. We're getting to be good at it. What's missing from this picture? There's no place for space! I don't mean the space that before Soyuz was called outer. I mean the space that is all over. He's saying that we're *made* of space. Yet we think nothing of it. Or if we think of it as something, it is the distance spaceflight overcomes. Physics needs to rise again with space.

With due respect to Smolin, strings are not what buried physics. Even money says that strings will turn out to be almost right. Gilder's got it—it was characters and plot twists. But she's writing the wrong book. It starts in Copenhagen, follows QM, takes Bohr's quantum jumps, embraces Heisenberg's uncertainty, then loses Bohm, ends up entangled. Next book she could start in Leiden, follow GR, fail to save the Lorentz ether, fail to make space jerky, fail to wed GR to Maxwell, fail to wed it too to QM, end up facing a beginning, find GR can't cope with it. And the key character in both her books—the one she wrote, the one she should—is Einstein.

Cosmology, it is now seen, is hung up on applying GR to the universe. The basic problem with this is GR's continuous and space is not. This gets its space-expansion story off on the wrong foot. Not surprising; GR gets invented by a guy who thinks the universe does *not* expand. Many other might-have-beens might be imagined. Gilder doesn't get to them—for her the universe would be a bridge too far. Yet if he's even halfway right this bridge leads to the land where physics' future lies.

Physics impacts on philosophy; the challenge for philosophy is to return the favor. Today most all of those who make new physics have a PhD—they're doctors of philosophy. And yet philosophy's a subject many of them never study although philosophic issues loom large over physics. Is its object to illuminate the world, to understand it better? Or is it to predict it more precisely? Many of the many who may say 'predict'—disciples though they may not know it of the neo-positivist school—may think that to predict it *is* to understand it. Reichenbach would ask what *kind* of statements physics makes about reality. Explanatory or numerical? Before she walked into my life I knew there were two views on this. Now, thanks to her, I have a head-full of both sides. His half of my head backs the minority.

Like Finkelstein's his bet is that intelligible theory ought to blaze a better trail for calculation, that math might lead to better physics if it's guided by a concept of what *is*. As I put down the books and surface for some near-sea air, I'm thinking his position's no surprise. He's chained in Plato's Cave. He is asking the Cave question physicists have long forgotten: Why?

My gray mood's gone. I'm rambling but I'm bursting with a feeling that I'm going somewhere and the sun will shine. I see that his Beginning shifts from what is seen upon the screen to what is going on. The complexities of seeming-simple entities unfolding flabbergast my mind. I can't envisage how its physics may surpass that of a soon-to-seem-simplistic picture of the world. And yet I bet it will.

I stumble on what Prantzos says about the study of the universe. A vast amount of information is out there for physics' eyes to see. And there are wild ideas about what is out there beyond the range of telescopes. At least they now seem wild to me, cozied up with Frank's Beginning tucked into its file on my hard drive. Some physicists say we live in an oddball corner of a universe that's infinite; the local laws of physics vary, ours just chance to be sublime. Or others assume an infinity of universes sprouting from each other like a cosmic Christmas cactus overdosed on cytokines. The Anthropic Principle, they say, explains why we should find ourselves in ours. Now and then their learned papers flash a flourish of equations. It looks to me like frantic physics, like their heads have lost their chickens.

In this kind of company the universe begat by the Beginning appears bland. Looking from our perfect planet past our just-right sun, we are immersed in a plain galaxy of some 400 billion stars. The Milky Way itself is in the Virgo Supercluster of perhaps ten thousand galaxies. Beyond it the astronomers can see or try to see about 300 billion more; nothing special about any of them. So far all the measurements say physics everywhere is all the same. The concept that it must be oddball elsewhere is invented to explain why it is, or so it is said, so oddball here. The Beginning brings a different perspective to all this. It says that over the astronomers' horizon lies a finite universe comprising at a given Move a zillion—any Tock, it's an exact number with two hundred or more digits—Flecks of space. It says that what astronomers would see there, if they could see, is more of the same. How can they know if it is so if they cannot ever see it? Well, they can't. But they can kick the tires of his Beginning, check if it explains what they can see. If so, the impulse to imagine oddball stuff beyond the astronomic pale may soon subside.

Meanwhile Frank offers up a single picture all the way from a sub-sub-sub-sub-atomic particle to the whole universe beyond the part of it that we can see. Filling in this picture may be Google Earth on steroids. It will need a new

approach. The old approach would start with something—space, let's say—and try to quantize it. Quantizing this or that as *policy* turns out to have its limitations. Even its successes leave the feeling that, though doing more, they say much less. In a letter Einstein says, 'I do not believe that it will lead to the goal if one sets up a classical theory and then "quantizes" it.' That Einstein says it will not work does not mean that physics drops it. Surveying the scene some fifty years later, Hu says this approach 'has been pursued by general relativists for more than half a century.' A quantum theory based on the Beginning will soon end all that. It will be already quantized, not as policy, but as the way it is.

Will Frank's insights foster a new post-post-positivist view? It's Comte who in the latter 1800s sets the positivist doctrine up to later infiltrate a hundred years of physics. In 1940 Jeans, by now beknighted, is a positivist physicist. He writes of physics with a sense of resignation, almost of defeat. We have, he says, five senses and they limit us. Our minds, he says, know only what the senses tell:

> Our minds can never step out of their prison-houses to investigate the real nature of the things … which inhabit that mysterious world out beyond our sense-organs. … Our studies can never put us into contact with reality, and its true meaning and nature must be for ever hidden from us.

What would Jeans make of Frank's excursion? His doctrine says that Frank's reality's all in his head. What would it make of the reality that it is all in mine? As far as I can tell he has no senses. Lacking senses Frank sets out to make some sense of things he thinks. Should his success suggest to physicists that positivist doctrine is too simple-minded for the care and feeding of their minds?

Lazaridis does not need persuading about care and feeding. He invests big bucks in physicists and in a place for them to talk and think. He sees how physics fosters the economy; he says 'the largest return on investment belongs to theoretical physics.' So he puts P.I. on physics' map. P.I.'s Director says its mission is 'trying to create conditions like those in ancient Greece, which saw the flowering of ideas because people looked at the world with new eyes.' Lazaridis simply says we need a new discovery. He no doubt knows that Feynman said, 'A new idea is extremely difficult to think of. It takes a fantastic imagination.' A hundred million dollars later B-T takes off, discovery in hand but undiscovered, on a bike. Will his twist and the Beginning help the P.I. people take another look? My bet is Tweedles link to flowering ideas. Or, to mix my metaphors, where'er I look there's low-hung fruit—that's Edmund Gosse—for physics' picking.

P.I. (not an accidental acronym; but do they know it also stands for a detective?) succors seven sorts of research. Five of them connect with the Beginning. Nice to think that's why she snooped around but not. And Frank's a bit like Tully Bascombe in *The Mouse That Roared*. Tully's the commander of the army of

Grand Fenwick who is charged with waging war against the USA. He's not supposed to win. And Frank was never meant to consummate the quest or even get the job.

I've almost hit my stride when she comes banging in and with a hurried Hi heads for her desk. I've never sneaked a peek there but she doesn't seem to keep much in it. Now I'll never know for sure. It all fits in a Barney's New York shopping bag. This doesn't mean that she was in New York—there's one on Wilshire—but what *does* it mean? I focus half a mile behind my screen, hearing her bag crunkle while I rack my brain. Maybe this is not a clue. Not the bag; her coming in, her cleaning out. Maybe it means nothing.

Once she's bagged her bric-a-brac she's nonchalant. Or disingenuous. She's like: That's tidier. And then: Still writing it? A smile that seems to say she really cares. I mutter something noncommittal. I can't let her spot what Frank is doing. After all, *he* doesn't work for her. He would tell her no more than Tar Baby would Br'er Rabbit. And he never says a word about her either. Does he know that she exists? Staring at my screen I try to keep my deadpan dead.

As soon as she has gone I get back at it with, not knowing why, a sense of hurry. What to do? If he was here he would not help with wrapping up. Fleetingly I ask myself: Why do I do it? Seems *he* thinks it is already done. But he is the inventor not the writer. I recall Sartre says a student painter asked his teacher how he'll know his work is done. I google it to get the exact answer: 'When you can look at it in amazement and say to yourself "*I'm* the one who did *that!*"' This, I think, is why I do this now.

Does this also tell me what to do? Why do I think, *again*, that the Beginning isn't physics? If a label's needed I like natural philosophy. It aims to charm or possibly persuade practitioners of physics. Maybe some of them will walk or even run with his ideas. If they do, how far could physics go? They might rejig it and seed fields of innovation; they might even give a boost to the economy. A modest enterprise, I almost hear him say. Right now it seems like things are stuck after a hundred years when, quid for quid and mark for mark and franc for franc and buck for buck, basic physics was by far the best investment a society could make.

What if physics were to find a new beginning, giving basic science a new chance to be the engine it once was? What if it does not? Alice Gast, as candidate-for-president of AAAS, writes, 'The problems we face are complex, but our approach to them must rely on fundamental science.' It isn't what she says but who she is and that she sees a need to say it that has me concerned. Could science lose its eminence? I see modern science as a flowering of understanding rooted in a bed of knowledge that has great complexity and depth, a grand human enterprise erected on a flimsy base of math and physics. Why is it reminding me

of Mandelbrot?

Horgan calls this set a bottomless phantasmagoria of baroque imagery. It's created by an elegant expression:

$$z = z^2 + c$$

Here c gives the position of some point that's picked by a set-tripper; z is the point where the tripper will next trip. Step one, z is zero. Multiply it by itself and add c to get a new point z; insert this back as a new c. And then it's like the recipe for flaky pastry, roll and fold; repeat this many times. If z never steps outside a radius-two circle, c is in the set, its color's black. For points that fall outside the set, code other colors. Code them for how many steps it takes for z to move outside the radius of two. This simple process paints a stunning scene. Any fragment of it may be magnified by ten, or millions, billions, trillions through gazillions. Each new level opens up new neighborhoods and every one is stunning. Anybody can see scenes that eyes have never seen before. Though each differs, unmistakably it's Mandelbrot. To restore my soul I set my work aside and take the Baroque Zoom trip to the Seahorse Valley. The Zoom trip stops but Mandelbrot goes on forever.

In my eyes this set's like science. Each rests on the same foundation—math. Each is whole, a unique thing entire; each is circumscribed—the set set in its circle, science contained in the universe; each is intricate beyond description and yet shows a certain elegance and beauty; each conceals a secret—simple rules that build upon an Initial Condition. And though as we discover each we might miscalculate some aspect, in principle it *is* so it is simply true.

Unlike the universe the set must use unreal real numbers. And so, though finite in 2-D extent, in depth it's inexhaustible. Gödel says that math is likewise inexhaustible. Does this apply to science too? It is no longer known to any person. It wanders along Mandelbrot-like valleys. One discovery's connected to another as time and minds reveal new vistas. Less often some long leap may make a new connection and some wholly new terrain comes into view.

Will science grow apace once it knows its own Initial Condition? Until now it has lived like an orphan who by self-adoption is himself his only parent, who knows nothing more than rumors of his birth. Though not for lack of trying. It's like Lasseter's lost reef—the golden grail of Oz prospectors—widely thought to be there but eluding every search. What does his Beginning offer? No mere leap to some new Mandelbrot-like valley. Rather it's as if, from Seahorse Valley, he has stumbled on its elegant equation.

That is what in fact he's missing. But he says that the equation must use integers and so foreshadows fundamental change for physics, which has long assumed the fabric of the universe is represented by so-called real numbers. He says

not. Those who seek the ToE should base their work on 1, 2, 3. A related implication is: Fundamental physics cannot use statistical ideas such as lines and distance. Though these have their uses they are worse than useless for investigating the real world. To have a chance of hitting pay dirt, real physics must be done with concepts that reflect the way things are. When limitations are accepted, Eisenstaedt opines, 'we may progress.'

This will need new physics and new math. Digging deep on arXiv, I find his unfolding universe would be a discrete causal structure to some physicists who work with Causal Sets. I am glad to know this though I'm not sure what I know. And what of those who work with strings? Well, as far as I can see he doesn't say that any one of their string theories is right. There's a world of difference between their 10-D Spacetime with its six Compactified dimensions and his 3-D space of 6-D Manifolds plus Tocks to total ten. Physicists cling to the former, sensing they are close to triumph. Susskind says, 'It's the leading hypothesis because nobody has another hypothesis which makes as much sense.' Could my Frank's Beginning be a basis for string theory that works?

All I can say is that he brings a whole new meaning to the 10-D world of strings. It's enough to earn a check against the Troubles with Strings. I leave the theory to the theorists. If they can pull it off they may become, in Smolin's words, 'the greatest heroes in the history of science.' He goes on to say (speaking of string theorists' Compactified dimensions) that, if they're right, 'No one in human history has ever guessed correctly about such a large expansion of the known world.' If Frank is right then one could also say: No one in human history has ever guessed correctly about such a *small* expansion of the known world. On one hand it would be another: *Vive la différence*! On the other: Is he human? Put so bluntly it sounds cruel but I wonder. I don't know.