S – Science, the Scientific Method & Scientific Models

Dear: When I'm walking, what I remember with '**S'** is just:

S: Science – humanity's greatest achievement and still our greatest challenge: the knowledge trail, the pathway for survival, the ladder to enlightenment, the stairway to the stars.

Sometimes, depending on my mood, I might add: *Not that some enormous scientific errors haven't been made and will yet be made, but if permitted to function, the scientific method is self correcting; even the colossal scientific mistake known as religion will eventually be corrected.*

In this chapter, I want to try to show you some general features of the scientific method, emphasizing "hypothesis formulation" or "model building". In later chapters (especially those labeled with **U** and **Z**), I'll sketch at least a little of the history of some scientific achievements leading to some scientific principles. In the "excursion" **Yx** (dealing with "Your Indoctrination in the Mountainous God Lie"), I'll try to show you what I mean by saying that religion is a colossal scientific mistake.

But before getting to any of those topics, before getting to the scientific "ladder to enlightenment" and "stairway to the stars", I should return to the "down-to-earth" practical question (which I left unanswered at the end of the previous chapter), namely: how can we obtain reliable knowledge for use as sound premisses for deductions? In philosophy, such an inquiry is part of "epistemology", meaning "the branch of philosophy that studies the nature of knowledge, in particular its foundation, scope, and validity."

For many people (including me!) the answer to the question of how to obtain valid knowledge for use as sound premisses for deduction is that the only way is *via* the scientific method. Roger Bacon (c.1214–94), perhaps the first person to clearly explain the scientific method, summarized it well:

> There are two modes of acquiring knowledge, namely by reasoning and experience. Reasoning draws a conclusion and makes us grant the conclusion, but does not make the conclusion certain, nor does it remove doubt, so that the mind may rest on the intuition of truth, unless the mind discovers it by the path of experience… The strongest arguments prove nothing so long as the conclusions are not verified by experience. Experimental science is the queen of sciences…

About 300 years later, advocating what's now called "the scientific method", Francis Bacon (1561–1626) wrote similar:

> Men have sought to make a world from their own conception and to draw from their own minds all the material which they employed, but if, instead of doing so, they had consulted experience and observation, they would have the facts and not opinions to reason about, and might have ultimately arrived at the knowledge of the laws which govern the material world.

Recently, Feynman summarized it well: "Observation, reason, and experiment make up what we call the scientific method… a way of trying not to fool yourself."

In fact, some people claim that the only way to gain any knowledge is *via* the scientific method, but I think the claim should be restricted to developing reliable knowledge for use in deductions about "how the world works". That is, I admit that humans have intuitive knowledge and that all animals (and plants!) have instinctive knowledge, apparently "programmed" in our DNA molecules. For example, instinctively I seem to know how to extract oxygen from the air I breathe, how to extract what my body needs from the food I eat, how to fight off viruses in the air and bacteria in food, and so on. Pity the poor person whose body doesn't have such instinctive knowledge. Similarly, I claim that I'm as moral as dolphins, having the intuitive knowledge to help my wounded cousins. But, Dear, if you want reliable knowledge for other than instinctive needs, in particular, if you want reliable knowledge for use as sound premisses for deductions, then I strongly recommend that you use the scientific method.

Now, Dear, I know that, in an earlier chapter, I already reminded you about the scientific method, a method that you've been practicing ever since you were a baby. But because the scientific method is so astoundingly important, I hope you'll have the patience to bear with me while I try to describe the method in other ways. In such descriptions, please notice not only (and once again!) how data are absolutely fundamental but also how experience, "common sense", and skepticism are involved. In what follows, in addition, please notice how, as a part of "hypothesis formulation", we construct various types of "models" of reality, with these "models" being verbal, pictorial, mechanical, statistical, mathematical, computational, or similar – or some complicated combination of these various types of models. I'll try to show you what I mean with an example.

EXAMPLES OF SCIENTIFIC MODELS – AND CONTROVERSIES!

I happen to know a family of five children – in fact, five grandchildren (GC) consisting of three girls and two boys. Let me label the girls, from oldest to youngest, as GC#1, GC#3, and GC#4, and let me label the two boys as GC#2 and GC#5. One day, I overheard these five rather-quarrelsome children arguing about models of this world of ours – as if they didn't already have enough to argue about! I'll sketch the resulting "discussion".

I don't know who first asked about the world, but I do remember that the oldest girl, GC#1, having the most "experience" and priding herself on her "common sense" started the controversy:

> "It's obvious! Common sense tells you that this world of ours is like a flat plate, around which travel the Sun, Moon, stars, and the various 'planets' (i.e., the 'wanderers'). Oh sure, on this flat plate there are a few bumps and indentations (which we call mountains and valleys), but those details are irrelevant. What's important is that my 'flat-plate model' is consistent with all the data: every morning the Sun comes up over the edge of the plate, and every evening, the Sun goes beneath the plate – and the stars become visible."

I, for one, thought that GC#1's flat-plate model of the world was quite good – and I could see why this model had dominated human consciousness for tens of thousands of years. The older of her two brothers (GC#2), however, obviously had troubles with her model – or just liked to argue:

> "Get real!", GC#2 started, "Haven't you ever seen a lunar eclipse? If you had, you'd see the shadow of the Earth on the Moon. You know it's our shadow; you can feel it: the Sun rises or sets on one side of you, and on the other side, you can see the Earth's shadow move across the Moon – and obviously the Earth's shadow is circular."

I thought that he made a good point, but apparently his older sister didn't:

> "So what?" questioned GC#1. "Did you think this world of ours was square? I didn't say it was square! Use you head. Use some common sense. The lunar-eclipse data obviously mean that this flat-plate world of ours is circular."

Now that she mentioned it, I had to agree that GC#1 hadn't previously claimed any particular shape for her flat-plate world, and thus I thought that her model withstood the challenge quite well – but then GC#2 attacked a second time:

> "That's stupid," he started. "Why don't you open your eyes and look for a change? Haven't you ever been to the beach? Haven't you ever seen a ship on the horizon? Sometime you otta watch one. As it moves away, first you can't see the water line, then you can't see the lower part of the hull, then you can't see the deck, and finally, even the ship's mast sinks beneath the horizon. So, obviously it's not a flat plate: it's curved!"

Well, on a clear day I've seen exactly what GC#2 described, so I had to admit that GC#2's argument was compelling. Undaunted, however, GC#1 fought back:

> "I know that," she responded, "I just didn't want to confuse you. I meant that the world's like a flat plate – as a first approximation. Actually, it's more like an upside-down dinner plate or an upside-down saucer or a Frisbee, which is why, when ships sail away, they seem to sink below the horizon. But that's just a refinement to my model; it doesn't distract from its essence."

I had to admit that GC#1's "Frisbee model" of the Earth seemed quite sensible and seemed to fit all the data, but then, maybe that's because I'm not quite so argumentative as GC#2:

> "Just a refinement," he blurted out, "get real! Common sense tells you that if the Earth were like a Frisbee, then the waters of the oceans would just roll off the edges! So, how come there's still water in the oceans?"

It seemed to me that GC#2 had a very good point, but then I guess I never appreciated GC#1's defensive skills:

> "It's obvious," she responded. "For a change, why don't you try using your head for thinking? Obviously there's land all around the oceans (weren't you standing on land when you saw the ship disappear beneath the horizon?), and with land all around the oceans, there's no place for the water to flow."

Actually, I thought that GC#1 was stretching her Frisbee model too far – and apparently GC#2 thought so, too, because he immediately attacked again:

> "That's crazy," he almost shouted, "do you plan to ignore all data that doesn't fit your model? Sure there's land almost entirely around the Mediterranean Sea, but not at the Strait of Gibraltar. And remember that, when the first sailors traveled to Gibraltar, they found not only that the Mediterranean Sea didn't flow out into the Atlantic Ocean but also, when the tide came in, water actually flowed from the Atlantic into the Mediterranean. How could that possibly occur on a Frisbee?"

But again, I obviously hadn't adequately accounted for GC#1's defensive skills – or maybe it was just her eagerness to argue:

> "Picky, picky, picky," she responded, adding: "Why do you keep ascribing to my model things I never said? I didn't say where the center of the Frisbee was. If you'd use some common sense, you'd see that obviously the Mediterranean isn't at the center, but somewhere closer to an edge. That's why the Mediterranean doesn't flow out into the Atlantic (except when the tide goes out). And the reason why the Atlantic doesn't flow into the Mediterranean is because the land blocks it. I mean, how obvious does it need to be before you see it? Maybe what you otta do is head out farther toward the edge: when you get to the edge, when you stare down to see how far you'd fall, then maybe you'd get the message!"

Well, I don't know if those two would have ever stopped arguing, were it not for the second oldest girl, GC#3. Maybe being the "child in the middle" had taught her to minimize arguments. Whatever the cause, when she heard talk of a Frisbee, she went and found hers, and when she heard talk about water on a Frisbee, she quietly poured a little water on hers. Of course the youngest girl, GC#4, wanted to play with the Frisbee, but then diplomat that she was, GC#3 distracted GC#4's desires by giving her a ball.

Meanwhile, GC#2 seemed deep in thought. Maybe it was GC#1's last argument that got to him. Maybe he was afraid of falling off the edge of the Frisbee! Whatever the cause, he kept staring at his two sisters arguing about the Frisbee and the ball – until he looked up and exclaimed:

> "Eureka!"
>
> "Huh?" responded GC#1.
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> "It's not a Frisbee, it's a ball! Look," he continued, "and for a change, apply a little common sense. Look at that ball, and think about it. The world's like a big ball. My 'big-ball model' of the world fits all the data. People think the world's flat, only because the ball is so big; during a lunar eclipse, we see the shadow of the ball as a circle; as ships sail away, they disappear below the horizon because they're going around the ball; and the waters of the oceans don't flow off the edge, cause there is no edge! Not only all that," he added, "but you can also see that the Sun, Moon, planets, and all the stars go around the ball in their circles."

I immediately liked GC#2's big-ball model better than GC#1's Frisbee model; therefore, I was rather surprised when GC#3, of all people, began to criticize it (of course, diplomatically):

> "Your big-ball model has some good points," she started, "but also some bad ones. First, I think there's something wrong with your idea about how the waters of the oceans would stay on the ball."
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> "Consider this," she continued, borrowing the ball from GC#4 and pouring some water on it (she's an amazing experimentalist!). "Notice how the water just flows off the ball!"
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> Then, upon returning the (wet) ball to GC#4, she added: "And I think there's trouble with your idea that the Sun, Moon, planets, and stars go around the big-earth ball in circles: if they did, then how come we see Mercury and Venus only near the horizon, how come they're never high in the night sky, and how come, sometimes, some of the planets seem to travel backwards?"

I was quite surprised at quiet little GC#3's knowledge. I guess there's truth in the old adage: "Still waters run deep." I then saw GC#2 begin to defend his big-ball model, just as GC#1 had defended her Frisbee model:

> "You're just a little kid," he started to explain to GC#3, "and you can't be expected to understand all the details. But let me try to show you. First, about the water flowing off your ball, you neglected to see that after the large amount of water rolled off, still the ball was wet. That means that some of the water stayed on this little ball – and this big-ball world of ours is so big that on it, that's all the oceans are: just a little bit of wetness. And as for all your "why questions" about the planets, you would need to see that planets move in circles upon circles: if you want to see what they look like, then next time you're on the internet, type 'Ptolemy circles' into some search engine, and you'll see what I mean."

But GC#3 was quite prepared to continue to criticize GC#2's big-ball model.

> "Well," GC#3 responded, "I already know about Ptolemy's circles, but I still think that your big-ball model is only partially right. In my view, any model should be simple and pretty, and your model of everything traveling around the Earth (which I'll call an 'Earth-centric' or 'Geocentric model') is neither simple nor pretty. It's not simple, because to explain the orbits of the planets, it requires circles upon circles upon circles. And it's not pretty, because it's not symmetric. It doesn't have the symmetry, for example, that Galileo saw through his telescope: he saw moons going around Jupiter. Further, more symmetric than your Geocentric model would be to assume, first, that the Moon goes around the Earth (just as you suggested and just as Jupiter's moons go about Jupiter), but then, that all of the planets and their moons – including the Earth and its moon – go around the Sun, i.e., a 'Sun-centric' or 'Heliocentric model', just like Jupiter's moons go around Jupiter."

As far as I could make it out, GC#2 was shocked that his kid sister, GC#3, was so knowledgeable. Even I don't know how she knew about Jupiter's

moons! But, boys being boys, he wasn't about to give up his model just because some little girl had challenged it:

> "Look," he said condescendingly, "I'm sorry if everything is not so simple and pretty as you'd like, but that's just the way the world is. The test of a model is not in how pretty it is but in its predictive power." [GC#2 seems to like alliterations.] "Thus," he went on, "the reason why your sister's Frisbee model failed is because it predicted that Columbus would sail off the edge – but he didn't. In contrast, my big-ball model not only predicts that he could sail around the entire ball, but the Geocentric model of our solar system is perfectly capable of predicting lunar and solar eclipses, as well as the motion of all the planets."

That seemed to be quite a "put down" for poor little GC#3, but apparently, GC#2 didn't intimidate her:

> "Sorry," she started, "but your big-ball model isn't good enough. One could argue forever about prettiness, but the real point is that your model is incomplete: all it does is fit old data (including the fancy fudging of your Geocentric model to 'explain' the behavior of the planets) without containing any explanation of how it all works. In contrast, let me show you more about my Heliocentric model."
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> "I'm all ears," responded GC#2.

Refraining from the obvious opportunity to comment on GC#2's appearance (middle-children get lots of experience in diplomacy!) GC#3 went on:

> "Look," she said (while picking up the ball in which GC#4 no longer showed any interest), "I say that how the system works is exactly the same as what happens to this ball if I let it go." Then, she dropped the ball, and after it had fallen to the ground, she added: "In my model, there's a force of attraction between any two masses, which I call a just a massive force of attraction, but some other grave fellow, perhaps by the name of Newton, called it 'the gravitational force'. Anyway, just as this force of attraction caused this ball to fall to the Earth, I say that there's a force holding the Moon as it moves about the Earth and holds the Earth (and similarly all the planets) as they move around the Sun. What's more, assuming only that this attractive force is proportional to the product of the two masses and varies inversely as the square of the distance between the masses, then not only do I get simple orbits for the Moon about the Earth and all the planets about the Sun, but I've found that I can get exactly the 'laws' that Kepler deduced from data for the orbits of all the planets. Besides all that, my model explains why the water doesn't flow off the Earth, and the reason isn't because it's just barely wet: the water doesn't fall off, because gravity holds it on."

Well, to say that GC#2 was stunned would put it too mildly. Yet, you've gotta give him credit: what he did was stand up, walk over to GC#3, and gently pat her on the head, as if to say "Good job, kid."

But not her kid sister: I don't know if GC#4 ever congratulated GC#3 in her whole life! As near as I can recall, GC#4's said:

"You're all bonkers."

"Huh?" responded GC#3.

"First," GC#4 started, "how can you say that your model explains stuff when you introduce such a weird idea as gravity? I mean, what's gravity? Why would one mass want to attract another? Do you think that the two masses are in love with each other or something? What's the basis of the attraction? All you've done is introduce a fictitious force into your model, whose purpose is just to explain Kepler's laws and why the Earth is wet. You're not explaining anything, you're just covering up unknowns with a fictitious attraction."

"And I assume you can do better," GC#3 responded, part defensively and maybe part sarcastically.

"Of course," said GC#4, "all that's required is a little common sense. Look at it this way. If you've ever been in an elevator, you might have noticed that you feel heavier when the elevator starts going up, and you feel lighter when the elevator accelerates down. So, as grampa used to say: 'Look at the limits.' Thus, if the elevator ever accelerates down with what you would call the acceleration of gravity (for example, if the elevator's supporting cables break), then it would be as if there were no longer any gravitational force."

"So? " inquired GC#3.

"So, use your head, " responded GC#4. "When was the last time you could make something real disappear just by going into a room (or into an elevator) and shutting the door? I know you've tried to do that many times by hiding in your closet, but has it ever worked? Similarly, in reality, there's no such thing as gravity: what you call gravity is what anyone else (someone who's doesn't hide in her closet to avoid reality) would call an acceleration."

"I don't get your point," responded GC#3.

"The point," said GC#4, speaking rather forcefully and seemingly trying to make the point with her finger, "is that your gravitational force is a figment of your imagination, derived from spending too much of your life in closets. In reality, some so-called 'gravitational force' doesn't cause an apple to fall toward the Earth, doesn't hold the oceans on the Earth, doesn't hold the Moon in its orbit about the Earth, and doesn't force planets to pursue their orbits about the Sun. It's all a Newtonian fiction. Instead, all these apparent motions are just primitive interpretations of force-free

> motions of masses in the neighborhoods of other masses, without understanding that it's four-dimensional space-time, itself, that's warped by the presence of mass."

What a chorus then developed! From GC#1, I heard: "Weird!" From GC#2: "You've lost it!" From GC#3: "Are you feeling okay? " But GC#4 seemed totally unfazed:

> "I don't care if you don't believe me!" she snapped, "but look at the data. My model, which I call my 'warped space-time model' (but some fellow by the name of Einstein called it something silly – like 'general theory of relatively'), is capable of explaining data that your primitive models can't even approach. Not only does my model explain all the data that you've incorrectly interpreted *via* your simplistic ideas about gravity but also my model is capable of explaining the old data for Mercury's orbit (which no Heliocentric model could explain), predicts that light will appear to be bent in the neighborhood of any mass (because, again, it's space-time, itself, that's warped by the presence of mass), and predicts that time changes in the neighborhood of mass – and all those predictions have now been amply validated by experiments. In fact, without that idea of time shift, the GPS data on your cellphone would be wrong – and mother wouldn't know where you are, even if you're not hiding in your closet!"

Well, there was no response from GC#3 or the older kids; I think that they were too startled by GC#4's knowledge. But meanwhile, GC#5 seemed to have taken all that he could tolerate. I think that the rest of the kids thought that it was all above him, but I had a sneaking impression that, in contrast, he thought that it was all beneath him. Anyway, apparently what attracted his attention was Einstein's name, because he blurted out:

> "Of all the intoxicating, egotistical stuff that any 'stein' ever held," GC#5 started, "the stupid stuff held by that one-stein must have made Ein-stein punch drunk. He wasn't consistent even with himself. He makes a force disappear by riding in a magic carpet that changes the metric of space-time and then has the audacity to say that this same non-force warps space-time! I agree that something's warped – but it's not space-time but a certain mug's brain."

The other kids seemed stunned. With mouths and eyes open, they leered at GC#5 – who continued:

> "Why is it that, when the rest of you start talking, then common sense leaves the room? When your youngest sister described that stuff about her elevator, why didn't at least one of you challenge her stupid statement: 'there's no way to determine if you're in an accelerating elevator or in a room influenced by the Earth's gravitational field.' That's idiotic: for one, forces are real; momentum is exchanged. And for another, in an accelerating elevator the apparent forces on all bodies are parallel, but in a room influenced by the Earth's gravity, all the forces point towards a single point, namely, to the Earth's center. So, unless you want to revert to a silly flat-plate

model of the Earth, there's no way for your kid sister to remedy this problem with her warped model. "

"Well, I rather liked the flat-plate model," said GC#1.

"I wonder why", GC#5 said sarcastically, "but instead, there IS a sensible model."

"Which no doubt you're going to explain," GC#2 mocked.

"Well," responded GC#5, seemingly wondering if it was worth his time, "Hasn't anyone heard of Dirac? As he showed, space – a total vacuum – isn't empty; it's chock-full with negative energy. Now, kid sister, here [which he said while patting GC#4 on her head] is right in saying that gravitational attraction is silly – I could identify many masses which aren't at all attractive – but some time or other (maybe when she was traveling in her free-falling elevator), she must have bumped her head to reach the conclusion that space-time is warped by mass: the only warping of space-time is the bump on her head."

"So," said GC#2, apparently the only one willing to challenge his kid brother, "do you have a better model?"

"Of course," GC#5 replied, condescendingly, "it's not difficult to improve on the dumb models that all of you have been promoting. First, ya gotta understand that any force of attraction is a figment of your imagination, and not because of little-sister's silly stuff about warped space-time, but because, in reality, gravity is a force of repulsion."

"Duh, " said an emboldened GC#1, "do you mean apples fall up, dumb-dumb?"

"Dumb-dumb yourself," GC#5 shot back, "maybe you'd want to keep quiet, so people might be fooled into thinking that you're intelligent. Here, look at this ball. Suppose that this sea of negative energy, which is everywhere around this ball, started exchanging stuff (call it 'gravitons', if you want) with this ball. In this exchange, momentum is transmitted to the vacuum as each graviton leaves; then, the equal and opposite momentum is given to the ball when the graviton arrives at the ball; the graviton realizes that this ball is an ugly piece of positive energy (somewhat similar to a certain sister that I could name); so, it leaps off the ball, kicking it backwards as it leaps, and returns to the vacuum energy. Notice what happens: the ball gets two kicks of momentum in the process, both kicks pushing it away from the part of space from which the graviton came (and an equal and opposite double-kick is given to the sea of negative energy, normally called space or the vacuum)."

"I don't get it," rejoined GC#2, "what's with the double kicks? That's as if there was a force of repulsion."

"That's exactly right," responded GC#5, apparently smiling at the possibility that his big brother wasn't quite so dumb as his big-ball model had suggested, "it's like two people playing catch with a basketball – or a heavier ball, like a medicine ball – while standing on a very slippery ice rink. And notice the obvious reason why what's-interpreted-as-a-force decreases as distance squared: with each region of space throwing out a steady number of 'gravitons', then because the surface area though which these gravitons pass increases with the square of the distance from their source, then the flux of gravitons (i.e., the number passing per unit area) correspondingly decreases as the square of the distance."

"I can see that," added GC#2, "but how can you get gravity out of that?"

"It easy," continued GC#5. "Look at what happens if the Earth, I mean the real Earth, is on one side of this little ball. On some places on this side, closer to the Earth, some positive-energy has solidified (i.e., in blobs of ugly old mass, which we call the Earth), squeezing out negative energy (i.e., space) from its location. To this, of course, negative-energy reacts (trying to push it away), but returning to the influence on this ball, it means that on the Earth-side of the ball, there isn't as much space (i.e., negative energy) pushing the ball away (because space can't locate itself there, courtesy the positive energy that's solidified as the Earth); consequently, this little ball feels more pushing from the space above it than from the space below it, and therefore, when I drop the ball, it moves toward the Earth."

"You're suggesting that gravity isn't a force of attraction between masses but a force of repulsion between space and mass?" asked GC#1.

GC#5 smiled that GC#1 was seeing it, and added: "Good. And not only that, you can see why what's interpreted as a 'gravitational force' depends on the product of the two masses: proportionality with the mass of this little ball because it's proportional to how much solidified energy that space is trying to get rid of, and proportionality with the mass of the Earth because it's proportional to the amount of negative energy (i.e., space) on the Earth side, from which space can't repel this little ball."

"Maybe," said GC#3, "but I don't get the point."

"Well dear sister," GC#5 sneered, "the point is that there isn't any force between masses (or between mass and light): there is neither a force of attraction nor a force of repulsion: masses, like most people, ignore one another. In addition, there is no warping of space-time by mass: if anything's warped, besides some people's brains, it's mass – being pushed around by space. What people don't seem to understand is that, in the case of what's called 'gravity', the interaction is between positive and negative energy: the sea of negative energy all around us is perpetually exchanging stuff (say 'gravitons') with positive energy – and perpetually finding positive energy inhospitable. So, the gravitons leave, and in the process, positive energy (solidified or as light) is pushed away from space. The result when two masses are nearby is that

> the masses move toward each other. Fundamentally, this repulsion between positive and negative energy is what caused the monstrous motion that astronomers call the 'Big Bang', and further, the other forces in Nature (such as the electromagnetic and nuclear forces) aren't forces between masses but forces between space and the various other tensorial properties (such as charge and spin and color) possessed by the solidified positive energy – but I'll explain that to you when you're older."

Stunned by their kid-brother's model, none of the other kids said a word. Nonetheless, I should add some comments. One is that (as far as I know) GC#5's model has never been reported in the scientific literature; therefore, it shouldn't be taken seriously. Another is to mention that his model is amazingly similar to the model that I had planned to mention (and still plan to mention) in Chapter **Z**! And most significantly, my third point is that, in contrast to the models proposed by the other four grandchildren, the model proposed by GC#5 provides no, new, testable predictions – and until he (or someone else) provides some new predictions of the model, it will remain (similar to the current model of the universe called "string theory") little more than speculation.

Soon, I'll comment further on the importance that models provide testable predictions, but now, Dear, please consider some general features of the above discussion among those amazing five kids, in part because the discussion has some uncanny similarities with the historical development of models of the Earth, but more importantly, because their method for developing their models is a good illustration not only for how all scientific models are developed but also for how knowledge is acquired that can be used as sound premisses for useful deductions. First, though, toward showing you that the only known way to develop sound premisses is *via* the scientific method, I want to return to some ideas in the previous chapter.

INDUCTION & THE SCIENTIFIC METHOD

In the previous chapter, I tried to show you the difference between induction and deduction, definitions for which are given in my dictionary as follows:

> **deduction**: *Logic* the act or process of deducing; reasoning from a known principle to an unknown, from the general to the specific, or from a premiss to a logical conclusion; also, a conclusion so deduced: opposed to *induction*.
>
> **induction**: *Logic* reasoning from particular facts or individual cases to a general conclusion; also, a conclusion reached by such reasoning…

This dictionary definition for 'induction' is correct but incomplete, in that it neglects to mention the point that I want to show you, namely, that the only way to reach a sound induction is *via* the scientific method.

Now, Dear, whereas 'induction' means "reasoning from particular facts or individual cases to a general conclusion", I want to start by mentioning a variety of different cases that can lead to various general conclusions (or principles). These can be of many different types, such as the following:

- Some general principles that you discover on your own (e.g., "mothers worry too much" or "grandfathers go on and on and on"),
- Some general features of human nature (e.g., "people are social animals" or "all people pursue their trio of survival goals", or similar),
- Some "folk wisdom" (e.g., "some days it just doesn't pay to get up in the morning", "nothing is certain but death and taxes", or similar, typically sad comments on life),
- Some fundamental scientific principles (e.g., "in the absence of external forces, the momentum of a system is conserved", "natural selection leads to evolution of life", or similar),
- Some pretentious proclamations by philosophers [e.g., Hegel's "the history of the world is none other than the progress of the consciousness of freedom", or his student's (i.e., Karl Marx's) "the history of all hitherto existing society is the history of class struggles", or my own "the history of the world is the history of dumb proclamations about the history of the world", or thousands of similar generalizations],
- Some sweeping generalization promoted by some political leader (e.g., "Democrats always…" or "Republicans always…" or similar),
- Some nonsense promoted by various religious leaders [e.g., "the Bible (or Quran or Book of Mormon), is the holy word of God and therefore is totally true"], or
- Some position promoted by various racists (e.g., "the Jews are God's chosen people" or "the Aryans are a superior race", or similar).

Let me also remind you that, as I tried to show you in the previous chapter, deductions can't lead to new information (i.e., all information is contained in the premisses) and that, thereby, if premisses are unsound, deductions from them can be dangerous.

In contrast to deductions (in which general principles are used to infer consequences for particular situations), in the case of inductions, information appropriate for particular situations is used in attempts to infer general principles. Thereby, in contrast to deductions, inductions have the potential to yield sound, general principles (such as when momentum is conserved, the certainty of death and taxes, that certain grandfathers go on and on and on, and so on) – as well as potential to generate some very dumb "principles" (such as "the history of the world is…", "Democrats always…", "the Bible… is true", "the Aryans are a superior race", and so on). The obvious question, then, is: How does one proceed, by induction, from information about particulars to sound general principles (rather than to dumb conclusions)? And, again, the answer is: the only known way to generate sound principles is *via* the scientific method.

Now, Dear, I wouldn't be surprised if your response to my claim (that reliable principles are gained only *via* the scientific method) is something similar to: "Your claim is nothing but a 'sweeping generalization'!" Well, kid, I agree it is! In addition, though, I claim that it's a sound generalization. That is, it's a general principle that's reached by the scientific method: by analyzing all available data, summarizing the data with this particular hypothesis (i.e., that the only known way to generate reliable principles is *via* the scientific method) and then by subjecting the predictions of that hypothesis to a continuous barrage of experimental tests. Don't you do the same to reach your generalizations?

Thus, Dear, consider some knowledge that you claim you've developed. For example, suppose that (by induction) you had inferred "mothers worry too much" or "grandfathers go on and on and on." By those inferences, you probably would mean that a particular mother and a particular grandfather behave in these manners, but disregarding those limitations on your generalizations, I would ask you to consider the method by which you reached your conclusions. Didn't you analyze available data before you conceived those hypotheses? Didn't you then submit your hypotheses to experimental tests? And, for example, doesn't this paragraph provide you with even more evidence that your hypothesis about a certain grandfather is valid? And as for the hypothesis about your mother, aren't more data being generated even at this instant that support your hypothesis?!

Yet perhaps you still object (skeptic that I'm glad you are). You might say (in, may I say, your typically argumentative manner):

I grant you that scientific induction is a useful and important way to develop knowledge, but what about mathematical, statistical, and logical inductions?

If you did ask such a question, Dear, I'd be tempted to respond: "I'll explain that when you're older." But having already experienced your reaction to such a response, I'll try to deflect your question another way. Thus, Dear:

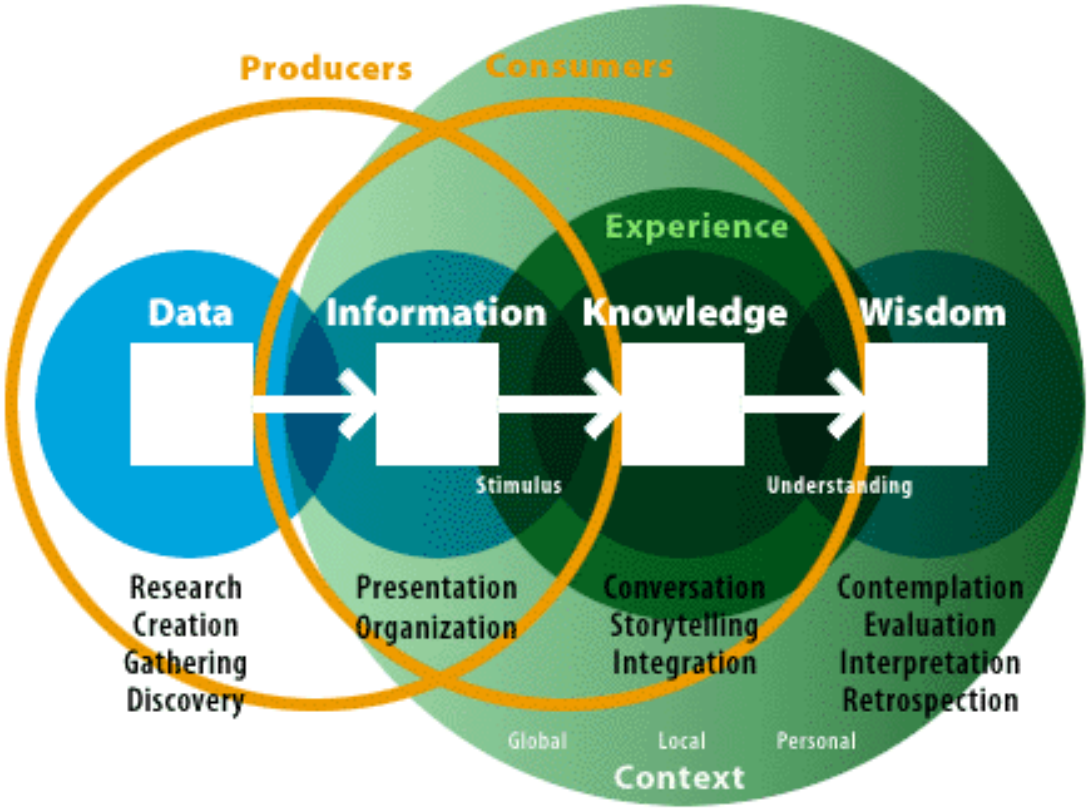
- As I tried to show you in the previous chapter, "mathematical induction" is restricted to a very special set of elements (namely, numbers). I'd even go so far as to say that "mathematical induction" is a misnomer, because it's actually a deduction from the premiss that the set of natural numbers is complete,

- "Statistical induction" is "just" part of the scientific method (specifically, a process by which one tries to get as much information as possible from data), and

- "Logical induction" doesn't generate knowledge, only hypotheses. Then, to transform hypotheses into knowledge, any hypothesis must be forced to provide predictions, and these predictions must be tested against data. For example, from knowledge that "these balls are red, those balls are blue, and those balls are green", you can't jump to the *knowledge* that "all balls are colorful." Instead, from such data, you can jump only to the *hypothesis* that "all balls are colorful" – and if you do propose such a hypothesis, you can bet that someone will hand you a black ball and say "black isn't a color" (i.e., the key to all knowledge is to test predictions of hypotheses against additional data). Thereby, Dear, perhaps you can see why philosophers such as David Hume (1711–76) and Karl Popper (1902–94) insisted that "logical induction" doesn't exist! As Popper wrote: "I hold with Hume that there simply is no such logical entity as an inductive inference; or, that all so-called inductive inferences are logically invalid. "

Consequently, Dear, I continue to claim that the only way to generate reliable knowledge is *via* the scientific method – and as was demonstrated by the argumentative kids earlier in this chapter, the scientific method starts by trying to make sense of some data.

But, Dear, all the above was just "preliminary stuff", and regardless of whether or not you agree with me that the only way to generate reliable knowledge is *via* the scientific method, let me get on to the "important stuff", namely, how to take the next steps (symbolized by the first two arrows in Shedroff's figure, referenced in the previous chapter and shown again below), i.e., the steps from data to information to knowledge?



Actually, there are three "first steps" in applying the scientific method – not counting the step of paramount importance, which is to start from a relevant set of reliable data! These three steps are:

1) Try to identify what information, if any, is contained in some data set,

2) Try to conceive of the cause(s) of whatever information is seen in the data, and

3) Try to develop some hypothesis (or build a model), which not only describes how the cause(s) led to the observed effect(s) but also predicts as-yet-unobserved effects.

Incidentally, all three steps aren't necessarily (or even usually) conducted by the same people (or even by people with similar competences). Thus, statistical analyses to try to identify trends and correlations in some data set require a special set of skills and tools; if statistical analyses reveal such trends and correlations, then scientists who know and can investigate processes search to try to identify potential causes; and then, when hypotheses are finally proposed, usually still other scientists design and conduct experiments capable of testing predictions of the hypotheses.

But until later chapters in this group, I want to delay comments on understanding processes, designing experiments to test "the truth" of some model, and so on. In the rest of this chapter, I want to focus "just" on the critical step of "tying to make sense" of some data.

ASSUMPTIONS FOR EXTRACTING INFORMATION FROM DATA

Assume that a reliable and relevant data set is available – a premiss that always should be checked! Then, the question that I now want to address is: how does one recognize information contained in the data? To help one to reach that goal, a number of principles (or premisses) are usually assumed. Rarely are these principles stated explicitly – which is rather unfortunate, because fundamentally, they're principles on which many (if not most) inductions depend. In turn, these principles were, of course, originally generated by the scientific method, i.e., by trying to make sense of still earlier data sets. I'll try to explain what I mean with some examples.

The most obvious premiss (on which depend all attempts to extract information from some data set) is that the data contain some information – a premiss that immediately you might challenge. You might ask, e.g.,

What if the data are just output from a random-number generator?

Well, Dear, if you did ask such a question, my response would be: if you can determine that the data are just the output from a random-number generator (and statistical methods are available to determine if that's so), then, thereby, you've gained some information (and it could be quite important information).

Assume that an Objective Reality Exists

Maybe the next most fundamental premiss on which all data analyses depend is that an "objective reality" exists external to each of us, regardless of our "subjective views" of this reality. Incidentally, this viewpoint (as a philosophy) is usually called "materialism" or "objectivism". By this premiss is meant that, if each of us could manage to constrain our subjective views of reality, then all views of this external reality would converge to a fairly consistent common view. For example, Dear, if all who know you would compare all their data about you, then a fairly reliable picture of at least your external features would probably emerge. I trust that this premiss of the existence of an "objective reality" doesn't shock you too much.

Assume Regularity

Another implicit premiss contained in many if not most attempts to make sense of some data can be stated in a manner something similar to: "There appears to be quite a bit of regularity in this universe." I realize that this statement of this *regularity principle* isn't very "forceful", Dear (which, as you'll see, is a characteristic of essentially all valid principles inferred by induction), but I hope you see that it's a principle that guides people in making many (if not most) of their sound generalizations. For example, consider again your alleged claims that your mother worries too much and that at least one of your grandfathers goes on and on and on. Weren't these inferences based on your observation of some regularity in the relevant data?

Consider another example. Suppose that after long and careful examination of all relevant data, my brilliant grandchild announced to the world the bold hypothesis: "Hey, every morning the Sun comes up!" No doubt you'd be pleased with this hypothesis, noting that, with its amazing predictive power, you could predict that the Sun will rise also tomorrow. Then, Dear, if I asked you how you managed to infer such a sweeping generalization from such a limited data set, I wouldn't be surprised if you responded: "'Cause"! 'Cause why? "'Cause it always does." Oh, do you mean that the basis of your hypothesis is that you recognized some significant regularity in this universe? "Yup."

This "regularity of the universe" is usually recognized either in time or space. If there's regularity in time (viz., "temporal regularity"), it's commonly described as some *repeatability* or *periodicity*. If there's spatial regularity, it's commonly described as some *pattern*, one of which is *symmetry*. If the data set under investigation can be expressed numerically (e.g., the time when the Sun rises each morning), then statistical methods are available (such as time-series analysis) that provide objective procedures to display regularities in such data – but here, I won't describe any of these methods; in college, you can take a series of statistical courses to learn about such methods.

Yet, and as somewhat of an aside, I want to comment on some subjective aspects of the human brain's apparent propensity to recognize repetitions and patterns – regularities that sometimes we see even when they're illusions! For example, that's the basis of many "optical illusions",

illustrations of which you can find on the internet (e.g., those that give patterns of dots, which our minds trick us to see, even in cases when the pattern is broken). No doubt seeking such regularity (e.g., in the surroundings) had survival advantages for our ancestors (e.g., if something was "unsymmetrical" or "asymmetric" with the pattern of particular group of bushes, then an alert ancestor would have learned that what broke the symmetry was probably a predator).

More fundamentally, maybe our "predilection for patterns" was derived from the "herding instinct". As I've mentioned before, there are survival advantages for fish to swim in "schools", birds to assemble in "flocks", and animals to roam in "herds" (because predators can attack only at the edges, and whereas the larger any group, then the smaller is the ratio of either the perimeter to the area or the surface to the volume, therefore in a group, more members would survive any attack by predators). Consequently, possibly "hard wired" into the animal brain (i.e., information contained within our DNA codes) is a resulting desire to recognize regularity.

And although the above contains a lot of speculation, I'll add the suggestion that all organized religions capitalize on this apparent tendency of the human brain to seek repetitions and patterns. To see what I mean, Dear, watch "the faithful" repeat their prayers and participate in their rituals (and then consider the human brain's desire for repetition), and examine religious art and architecture (and then consider the human brain's desire to find spatial patterns such as symmetry). Thereby, people can gain primitive feelings of "comfort" and "security" from regularity in time and space – even though these regularities are of human origin (as are the regularities in poetry and music). In fact, just as with optical illusions (when our brains trick us into seeing regularity when in reality there's none), apparently most religious people find regularity even when logic would tell them that the regularity is most likely an illusion.

For example, consider again the concept of prayer, which seems to be a common feature of all religions. As I mentioned in an earlier chapter, if one person's prayers (e.g., to do well on exams and get into a particular college with limited enrollment) are "answered", then someone else's "regularity" would be destroyed (e.g., someone who did as well on the exams and therefore expected to be admitted to the same college). Or if one person's prayer that an approaching tornado wouldn't hit his house were to be answered, then not only would the tornado endanger someone else, but the

science of meteorology would crash. Or if some god were permitted to stop the Sun in its path (or, stated more reasonably, stop the Earth from spinning) for three hours (as claimed in the Bible) or to stop the Sun from shinning for three days (as is claimed in the Book of Mormon), or any similar claim, then all of the science in physics and astronomy would crash.

That is, Dear, although the premiss that "there's quite a bit of regularity in the universe" doesn't preclude the existence of gods, it does require that, if there were any gods, they'd be required to "keep their cottin' pickin' hands off"! No miracles are permitted and no prayers can be answered, because otherwise, regularity of the universe would be destroyed!

And although the above analysis probably seem "logical" to most people, yet the logic isn't enough to persuade them to "cease and desist" in their prayers. They seek regularity both in the repetition of their prayers and in the rest of the universe, and so long as their prayers don't upset the regularity of the universe (thereby demonstrating that their prayers are pointless!), still they persist in the comforting repetition of their prayers. Never underestimate how much people are willing to pay for regularity.

Similarly, never underestimate people's commitment to the particular spatial regularity (or pattern) called symmetry. For example, when Galileo announced his support for Copernicus' idea that the Earth encircled the Sun [i.e., the "Heliocentric" (= Sun-centered) theory, thereby suggesting that the Heliocentric idea was more reasonable than the clerics' (or Ptolemy's) "Geocentric" (= Earth-centered) theory], the basis of his suggestion seems to have been his desire for symmetry.

In particular, when with his newly invented telescope Galileo saw what no one had seen before, namely, moons encircling Jupiter, he apparently concluded that the solar system would have more symmetry if, similar to the moons encircling Jupiter, the Earth and the other planets encircled the Sun. Meanwhile, some of the most vehement criticisms against Galileo was that observation of Jupiter's moons broke the symmetry that the clerics' had artificially constructed based on the number seven (e.g., with the number of days in a week), in turn derived from the observations that there were only seven moving astronomical bodies (i.e., the Sun and Moon and the five planets observable by eye) and from the fact that there are seven openings in the human head.

Assume Causality

Meanwhile, and more importantly, another general principle (implicit in all sound inductions and discovered by all animals millions of years ago) is the *principle of causality:* every effect has its cause. If you doubt my claim that animals discovered this principle millions of years ago (and my additional claim that those animals who didn't learn the principle of causality are now extinct), then, Dear, watch your dog the next time he smells a different odor (he knows that there's a cause), watch your cat the next time she hears a scratching sound (she knows there's a cause), and even watch your fish when you (once again!) disturb their water.

But then, you already know all this stuff. For example, I bet that, based on *the principle of regularity*, alone, you're quite prepared to announce to the world your brilliant prediction that the Sun will come up tomorrow (for which, undoubtedly, you would expect to receive a Nobel Prize). Then, saving the explanation for your second Nobel prize, I bet you'd be quite prepared to apply *the principle of causality* to announce to the world the reason for such regularity in the data: "'Cause the Earth spins on its axis, once per day!" What a brilliant child. You might even go on to apply causality to explain your other hypotheses, e.g., the reason why your grandfather "goes on and on and on" is because he's losing it.

Now, Dear, I know I already commented on the principle of causality in early chapters (some grandfathers do go on and on and on…), but I hope you'll be patient with me, not only because it's an extremely important principle, upon which the whole of science is built, but because it's much more complex than most people realize. In this chapter, I'll go into some aspects of one use of this principle, namely, in the construction of "models" of reality (whether these "models" are constructed using words, pictures, mechanical objects, mathematics, computer codes, or "whatever"). In a later chapter (**U**, which deals with Understanding and Uncertainties), I'll dig deeper into the principle of causality, to show you both its limitations and its more correct interpretation, and in the excursion **Yx**, I'll show you how all religion have failed to go beyond the first step in the application of the principle of causality.

For a while, however, I want to set those topics aside and push on to identify another general principle that's commonly used when one tries to make sense of some data set.

To Start, Assume Simplicity

This additional principle, which can be called *the simplicity principle,* might be stated something similar to: "If in doubt, choose simplicity."

This simplicity principle is used when developing and testing models to describe processes in the universe. Its use can be illustrated again with the experiences of Galileo. As I already mentioned, in his day there were two competing models of the solar system. One was Ptolemy's ~1500 year old Earth-centered (Geocentric) model, which was amazingly accurate but also, amazingly complicated (with its circles within circles within circles, to model the motion of the planets relative to the Earth). The other was Copernicus' Sun-centered (Heliocentric model), which was rather inaccurate (because Copernicus had incorrectly assumed that the Earth moved around the Sun rather than about the center of mass of the Earth-Sun system). Yet, Galileo chose to support the less-accurate Heliocentric model (until torture or fear of torture by the Catholic Church caused him to "recant") not only because he sought symmetry (as I mentioned a few paragraphs ago) but also because the Sun-centered model was simpler – and he relied on the principle: "If in doubt, choose simplicity."

Actually, though, there's more to the story: it should include more praise for early astronomers who investigated the Geocentric model [including Heraclides of Pontus, 4th Century BCE, Aristarchus of Samos, 3rd Century BCE (whom Copernicus cited), and Seleucus of Seleucia, 2nd Century BCE], more praise for the Alexandrian astronomer Ptolemy (c.83–161 CE) who developed the Heliocentric model, and more criticism of Galileo. As pointed out in the Wikipedia article on Heliocentrism,[1] Ptolemy clearly saw the simplicity principle – and a critical restriction on it:

> It is interesting to note that Ptolemy, himself, in his *Almagest* points out that any model for describing the motions of the planets is merely a mathematical device, and, since there is no actual way to know which is true [at least in Ptolemy's day], *the simplest model that gets the right numbers should be used.* [Italics added]

In contrast, Galileo pushed the principle of simplicity too far. As mentioned in another Wikipedia article:[2]

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[1] At http://en.wikipedia.org/wiki/Heliocentrism.

[2] At http://en.wikipedia.org/wiki/Galileo.

> Galileo also refused to accept Kepler's elliptical orbits of the planets, considering the circle the "perfect" shape for planetary orbits.

So, Dear: simplicity, yes, but not simplistic. The ability of a model to produce accurate predictions trumps simplicity any day!

As another illustration of *the principle of simplicity,* consider your other alleged inference, namely, that your mother worries too much. You allegedly reached this hypothesis, of course by induction, from trying to make sense of some data. To reach this conclusion, however, you used only *the principle of regularity* (finding some regularity in your data); you didn't yet apply *the principle of causality.* So, suppose I suggested that the cause of the regularity, the cause of your mother worrying so much, was that when she was a child, an alien monster zapped her with a special serum that made her worry. My grandchild's response:

> Grandfather [Ooops: there's that word again! Trouble ahead!] get real. First, my original hypothesis that she worries too much was based both on the regularity I saw in the data and in the symmetry I saw between her behavior and that of other mothers. And now, if you now want me to add causality, I'd say that a much simpler model than your weird hypothesis about aliens is simply that it's normal for all mothers to worry about their offspring, because in general, those animals that didn't learn this lesson are now extinct.

Which makes me wonder why I'm going through all this stuff about regularity, repeatability, patterns, symmetry, causality, modeling, and simplicity, when already you seem to know it all! But maybe it might be useful if I added a few words of caution and alert you to some other words.

My cautionary words are related to seeking simplicity, namely, be careful that you don't seek so much simplicity that your model is simplistic (or even silly). A case in point is "the God model". I doubt that anyone would argue that the God model (for how the universe was created, etc.) isn't simple; little kids as well as adults with childish minds gobble it up! And actually, as you can find on the internet, even some people with advanced degrees in various technical fields (but rarely in scientific fields) develop elaborate arguments to try to demonstrate that the God model (e.g., "intelligent design") is consistent with all available data. And although their machinations (viz., "plots and intrigues; schemes") raise the ire of scientists, yet I admit: I've been impressed with the deftness of the God-model defenders to duck so many of the slings and arrows shot at them!

There is, however, one set of criticisms that, not only have "God modelers" not been able to refute, but that totally destroys the credibility of their model. It's that all that "God modelers" do is just manipulate their model (especially their definition of the word 'God'!) to meet whatever objections are raised, never providing predictions from their model – at least, not one that can be tested by people who are still alive! It would take too long for me to show you details of what I mean, Dear, but if you want to explore them on your own, then search on the internet using words such as "intelligent design" +"god of the gaps".[3]

In fact, a similar attack could devastate GC#5's model (outline earlier in this chapter), in which he argued that both Newton and Einstein were wrong and proposed that gravitation was not an attraction between masses but a repulsion between positive and negative energies. Certainly his model is simpler than Einstein's, but even if GC#5 (or his grandfather!) could demonstrate that his model satisfies all known facts (manipulating his model so that it would!), yet until he provides at least one prediction that's unique to his model, it'll "never fly". Of course, maybe he (or his grandfather) will provide such predictions when he (or his grandfather) is older (☹), but until then, his model will be another illustration that testable predictions always trump simplicity.

It might be useful to mention, also, that sometimes people use words other than 'simplicity' to mean the same thing. For example, rather than mention 'simplicity', some people refer to 'succinctness', "the principle of parsimony", or "Ockham's razor". As I mentioned in an earlier chapter, this "razor" was named after the 14th century logician William of (the English village of) Occam (or Ockham), who wrote "*Pluralitas non est ponenda sine necesitate*", which a later Latin scholar wrote as "*Entia non Sunt multiplicanda praeter necissiatem*" (viz., "Entities should not be multiplied beyond necessity") and which Newton wrote as:

> We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.

As I also mentioned in an earlier chapter, about 2,000 years before Newton and therefore ~1600 years before William of Ockham, Aristotle hinted at the

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[3] A particular example, one that will take you multiple hours to read, is at the Forum of the Internet Infidels Discussion Board at http://www.iidb.org/vbb/showthread.php?t=197924.

condition of succinctness. In his *Metaphysics* (Bk. VIII, Pt. 6) he began guessing how many "prime movers" (i.e., gods) there were and concluded:

> When the consequences of either assumption are the same, we should always assume that things are finite rather than infinite in number…

I should also add that there's no guarantee that the principle of simplicity will yield a valuable hypothesis: the simplest hypothesis may be found to yield predictions that are false. Instead, the principle is more just a "rule of thumb", derived from experience. That is, experience has shown that, to try to understand some data, the best place to begin is with the most obvious explanation, adding more complicated reasons only when they seem to be necessary. For example, Dear, an alien monster may in fact have zapped your mother, but if your explanation for her concern for her children fits the data, then I would agree that your simpler hypothesis is preferable to my more complicated "explanation". But enough (too much?) about simplicity and succinctness – and about an objective reality, with its regularity and causality. Now, I want to move on to the next step in the scientific method, that is, how to formulate hypotheses that, first, summarize some data.

FORMULATING HYPOTHESES

I'll use the imagined arguments among the five kids, described earlier in this chapter, to examine "hypothesis formulation" or "model building". Notice that, to formulate their models, all five kids adopted the ideas that all relevant data were reliable and that there existed an objective reality. In addition, to try to "makes sense" of the data, notice that they all adopted the principles of regularity, causality, simplicity, and succinctness – although disagreements arose from applications of the principles of simplicity and succinctness (disagreements that degenerated to insults about the quality of the "common sense" used to "make sense" of the data). What I especially want you to notice, Dear, is first, how common it is to use analogies to try to make sense of some data, and second, how old analogies are abandoned in favor of new models capable of interpreting additional data.

Model Building Using Analogies

To start, consider the hypothesis proposed by GC#1. At first, she proposed that the Earth was "like a flat plate", and with this model, she was able to make sense of data about the Sun coming up each day and disappearing each night, as well as the appearances of the Moon, planets, and stars; i.e., "the

cause" of all this "regularity" in the data was the assumed motion of the "heavenly bodies" around her imagined, flat plate. Under pressure from the data brought up by GC#2 (about how ships seem to slide over the horizon), however, she revised her "flat-plate model" so that the Earth was more "like a Frisbee", with "the cause" of the visual effect (of ships seeming to slide over the horizon) being the Frisbee's curvature.

Although GC#2 didn't completely destroy GC#1's Frisbee model with his proposal that the water of the oceans would flow off the edges of her Frisbee (because, first, she assumed that the Frisbee was ringed with mountains, and then, she moved her location from the center of the Frisbee), it seemed clear that she was doing a lot of manipulating, trying to defend her model. If GC#2 had accepted her challenge about going to the edge of the Frisbee, then with the additional data of his not falling off any edge, he could have demolished her Frisbee model. As it was, instead, he proposed the bold hypothesis that the Earth was, not like a Frisbee, but "like a big ball". Notice again, Dear, the reasoning by analogy.

GC#2's big-ball model of the Earth faired quite well, not only "making sense" of all the data fit by the Frisbee model, but also eliminating any problem about falling off any edges. But when GC#2 went on to claim that the Sun, Moon, planets, and stars traveled around his big ball in circles, GC#3 began to object. She had many objections: as far as she was concerned, he hadn't provided an adequate reason (or cause) for why the waters of the oceans wouldn't fall off the big-ball Earth, and as far as she was concerned, his description of the retrograde motions of Mars and Venus was far too complicated, with its circles upon circles upon circles, seemingly contrived just to fit the data. GC#3 then made an amazing proposal: not only that there was a force of "gravitational attraction" between heavenly bodies ("like the force between an apple and the Earth") but also that it was this force that held the waters of the ocean on the Earth and that dictated the motions of the heavenly bodies.

Now, I don't want to reconstruct the entire argument, but first notice that GC#3 specified even the form of this proposed gravitational force that she used in her (mathematical) model, and then, notice some of the analogies used by the other kids: GC#4 used an analogy about being in an elevator to eliminate GC#3's gravity, replacing it by "warped space-time" (just as it's reported that Einstein did), and GC#5 used an analogy about two kids playing catch with a basketball (or medicine ball), while standing on ice, to

replace GC#4's warped space-time (and GC#3's gravitational attraction) with repulsion between negative-energy (space) and positive-energy (mass and light). And in case a certain grandchild is now repeating her mantra "certain grandfathers go on and on and on…", let me get to my point.

Limitations and Dangers of Analogies

Actually, I want to make two points. My first point is that, when we try to make sense of some data, when we try to gain some understanding of some information, when we try to develop one or more general principles from information only about particulars, then commonly we develop our models by analogy. In the process, of course we don't (or shouldn't) abandon the many premisses I mentioned earlier: we assume (but should check!) that the data are reliable, we assume that they describe some part of an objective reality, and we normally adopt premisses about regularity (i.e., repeatability in time and commonly some symmetry in space) and causality. Also, as a first step, we assume simplicity. But in all of this, normally we construct a model (mental, verbal, physical, mathematical…) based on analogy.

And the second point I want to make is to urge you to be extremely careful: reasoning by analogy can be dangerous, leading to horrendous errors – errors that can only be corrected by forcing your model to yield predictions, and then subjecting those predictions to a battery of experimental tests. The dangers of reasoning by analogy, of drawing inferences (*via* induction) by analogy, of proposing hypothesis based on analogy… are so great (and arise so frequently) that I want to spend the rest of this chapter trying to "hammer the point home."

Dear: never trust inferences drawn by analogy. You can NEVER "prove" that anything is "true" by analogy. The only superficial exception to that statement is if the analogy is "perfect", e.g., that the Earth is not analogous to a Frisbee, or a ball, or… but in fact, is one! But that's only a superficial exception to the "rule" (that you can never prove that anything is true by analogy), because then, you're not dealing with an analogue but a duplicate!

Otherwise, Dear, if you ever hear someone say that the Earth is like… or an ecosystem is like… or God is like… then realize that someone is "just" trying to develop a model of something, that no analogy should be accepted as perfectly accurate, and therefore, that "truth" can never be transferred from the analogue to reality.

As I'll show you in the next chapter, the only known way to "test for truth" is to subject predictions of any hypothesis to a never-ending series of experimental tests. Throughout history (and certainly not just in science), failures to realize such limitations in all reasoning by analogy has led to some absolutely horrible claims of "truth". In the rest of this chapter, I'll show you some examples.

Example 1: The "Laws of Manu"

For my first example, consider the "Laws of Manu", which I've seen suggestions are from about 1500 BCE and which are written in *The Veda* (which you can find on the internet). In *The Veda*, which may have been written in about 1200 BCE and which is the "holy book" of Hinduism, the "reason" for different classes of people (according to Hindu clerics) is as follows [to which I've added some notes in brackets]:

> 87. [To] protect this universe [although it's clear that these ideas are designed to protect the caste system, with the clerics at the top of the social structure] He [the creator of the universe], the most resplendent one, assigned separate (duties and) occupations to those who sprang from his mouth, arms, thighs, and feet.
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> 88. To Brahmans [i.e., to the priests, who the priests say sprang from the chief god's mouth – to be his "mouthpiece"!] he assigned teaching and studying (*The Veda*), sacrificing for their own benefit and for others, giving and accepting (of alms) [and like parasites, living off productive members of society].
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> 89. The Kshatriya [the leaders and warriors, who sprang from the chief god's arms, i.e., the next lower class, after the priests – for after all, wasn't it obvious that the priests were the highest class?] He commanded to protect the people, to bestow gifts, to offer sacrifices, to study (*The Veda*), and to abstain from attaching himself to sensual pleasures [and, perhaps needless to say, abstain from overthrowing the priesthood!];
>
> 90. The Vaisya [the merchant class, who sprang from the chief god's thighs] to tend cattle, to bestow gifts [especially to the priests], to offer sacrifices [again to the priests!], to study (*The Veda*), to trade, to lend money, and to cultivate land.
>
> 91. One occupation only the lord prescribed to the Sudra [the lowest class, who sprang from the chief god's feet], to serve meekly even these (other) three castes.

The above was the source of the horrible "caste system" (remnants of which persist in India to this day); it may be the first recorded ridiculous case of reasoning based on analogy, reasoning that in reality is nothing more than rationalizing, attempting to "justify" another parasitic priesthood.

The errors in the Hindu clerics reasoning by analogy could have been averted not only if the conclusions had been tested against reality but even if the people had demanded a test of the premiss. For example, imagine the following challenge.

> Okay, you clerics, you say that "the resplendent one" made you clerics his mouthpiece "to protect the universe"? Well, then, show us that, if you clerics are removed from power, if you are forced to fight the wars, to farm the land, and to serve as slaves, then the stars will fall from the sky, that the Sun won't shine, that the birds will no longer fly, and that plants will not longer grow. Until this happens, then you can take all deductions from your premiss, your stupid argument by analogy, and your caste system – and blow them out your collective ears!

Or maybe they could have just repeated my granddaughter's challenge: "Show me the data!"

Example 2: Aristotle's Fallacious and Horrible Argument for Slavery

Idiocy similar to the "Laws of Manu" can be derived by analogy without starting from some erroneous principle found in some "holy book". For example, consider the following fallacious and horrible argument by "the father of logic", Aristotle, "justifying" slavery.

This example illustrates both 1) the danger of not constraining reasoning with data and 2) the error of (all) reasoning by analogy. It's from Aristotle's book entitled *Politics,* to which I've added some comments in brackets and in some cases added paragraphs breaks, when my comments seemed (even to me!) to cause significant breaks in his argument.[4]

> In the first place there must be a union of those who cannot exist without each other; namely, of male and female, that the race may continue (and this is a union which is formed, not of deliberate purpose, but because, in common with other animals and with plants, [humans] have a natural desire to leave behind them an image of themselves), and of natural ruler and subject, that both may be preserved. For that which can foresee by the exercise of mind is by nature intended to be lord and master, and that which can with its body give effect to such foresight is a subject, and by nature a slave…
>
> Let us first speak of master and slave, looking to the needs of practical life and also seeking to attain some better theory of their relation than exists at present. For some are of opinion that the rule of a master is a science, and that the management of a

[4] Aristotle's *Politics* is available at www.classics.mit.edu.

household, and the mastership of slaves, and the political and royal rule… are all the same. Others affirm that the rule of a master over slaves is contrary to nature, and that the distinction between slave and freeman exists by law only, and not by nature; and being an interference with nature is therefore unjust.… [And therefore, Dear, notice that some people, even in Aristotle's day, saw that slavery was wrong.]

But is there anyone thus intended by nature to be a slave, and for whom such a condition is expedient and right, or rather is not all slavery a violation of nature? There is no difficulty in answering this question, on grounds both of reason and of fact. For that some should rule and others be ruled is a thing not only necessary, but expedient; from the hour of their birth, some are marked out for subjection, others for rule… [Notice, Dear, that so far, Aristotle has given neither 'reason' nor 'fact' – just opinion.]

Such a duality exists in living creatures, but not in them only; it originates in the constitution of the universe; even in things which have no life there is a ruling principle, as in a musical mode. But we are wandering from the subject. We will therefore restrict ourselves to the living creature, which, in the first place, consists of soul and body: and of these two, the one is by nature the ruler, and the other the subject… [Notice, Dear, that he's now introducing an analogy, and please reconsider the principle that "proof" by analogy is never adequate – unless the two subjects are not only analogous but identical (in which case, there's no analogy).]

But then we must look for the intentions of nature in things which retain their nature, and not in things which are corrupted. And therefore we must study the man who is in the most perfect state both of body and soul, for in him we shall see the true relation of the two; although in bad or corrupted natures the body will often appear to rule over the soul, because they are in an evil and unnatural condition. [Five hundred years later, the Christian clerics adopted this silly idea of a soul that was separate from one's body, and 2,000 years later, Descartes built his philosophy around it, even though the idea doesn't have a shred of data to support it.]

At all events we may firstly observe in living creatures both a despotical and a constitutional rule; for the soul rules the body with a despotical rule [which is quite a claim, given that no one has ever shown that a soul exists!], whereas the intellect rules the appetites with a constitutional and royal rule. [Well, I don't know about the "royal rule", but I suppose one could call it a "constitutional rule", insofar as one's thoughts could be described as defining a "constitution".] And it is clear that the rule of the soul over the body, and of the mind and the rational element over the passionate, is natural and expedient [He's using undefined terms; he might as well have written 'good', which would then need to be defined relative to some objective]; whereas the equality of the two or the rule of the inferior is always hurtful.

The same holds good of animals in relation to men; for tame animals have a better nature than wild [Again: "better" in what sense? If the objective of wild animals is for their genes to survive, as no doubt it is, then their "nature" seems amazingly

"good" for the purpose], and all tame animals are better off when they are ruled by man; for then they are preserved. [So, apparently he did recognize that the goal was survival; I then wonder why he didn't see that the most serious threat to the survival of wild animals was the influence of humans, whose interference then shouldn't be said to be "for the better".]

Again, the male is by nature superior, and the female inferior [In what sense? Having babies?!]; and the one rules, and the other is ruled; this principle, of necessity, extends to all mankind. [And why is this male chauvinism "of necessity"? Is it necessary for the male, for otherwise he'd need to do more work, and necessary for the female, for otherwise he'd beat her? So, is the operating principle: "might makes right"?]

Where, then, there is such a difference as that between soul and body [there isn't!] or between men and animals (as in the case of those whose business is to use their body, and who can do nothing better), the lower sort are by nature slaves, and it is better for them as for all inferiors that they should be under the rule of a master. ["Better" in what sense; most slaves don't think it's "better"!]

For he who can be, and therefore is, another's [property!] and he who participates in rational principle enough to apprehend, but not to have, such a principle, is a slave by nature. [How Aristotle could make such a statement, with so much data available that conflicts with such an assessment, is astounding: as with most if not all ancient societies, the Greeks would engage in an enormous struggle against some adversary (such as the Trojans or the Persians); then, should the Greeks overcome their near-equal foes, the Greeks would take prisoners as slaves; and Aristotle then had the audacity to say that that such slaves had no "rational principle". If that statement were correct, why did the Greeks have such difficulty defeating their adversaries in battle?!]

Whereas the lower animals cannot even apprehend a principle; they obey their instincts. And indeed the use made of slaves and of tame animals is not very different; for both with their bodies minister to the needs of life [of the owners!]. Nature would like to distinguish between the bodies of freemen and slaves, making the one strong for servile labor, the other upright, and although useless for such services, useful for political life in the arts both of war and peace. But the opposite often happens – that some have the souls and others have the bodies of freemen. [So why is that? Ever think of checking your premisses?]

And doubtless if men differed from one another in the mere forms of their bodies as much as the statues of the Gods do from men [riiiiiiiight], all would acknowledge that the inferior class should be slaves of the superior. And if this is true of the body, how much more just that a similar distinction should exist in the soul? But the beauty of the body is seen, whereas the beauty of the soul is not seen. It is clear, then, that some men are by nature free, and others slaves, and that for these latter slavery is both expedient and right…

How, Dear (I hope you are wondering), could such a brilliant person as Aristotle make such colossal errors? I'll respond by suggesting ways for you to try to avoid similar errors:

- Take extreme care when trying to identify causes. Aristotle argued that the cause of slavery was some "natural order", rather than the obvious reason: another horrible application of the law of the jungle.

- Take extreme care that your reasoning is more than just rationalizing. I suspect that Aristotle was searching more, not for a reason for slavery, but for some salve to soothe his shame for participating in slavery.

- Take extreme care with analogies. Analogies can help us organize our thoughts, but no matter how close an analogy is to the reality we're dealing with, we can never prove something by analogy: at best, an analogy will suggest some hypothesis; then, the hypothesis must be subject to experimental tests (and more tests, and still more tests!), before we can begin to gain confidence that our hypothesis might be valid.

- Take extreme care to ratify your reasoned results against reality. Again, Dear, if someone as brilliant as Aristotle could make such colossal errors in his "reasoning", then, the rest of us should essentially never rely solely on our reasoning.

Bertrand Russell succinctly summarized Aristotle's failure to rely on data:

> Aristotle maintained that women have fewer teeth than men; although he was twice married, it never occurred to him to verify this statement by examining his wives' mouths.

And in the case of slavery, it's not as if relevant data weren't readily available to Aristotle, data that could have easily demonstrated that his reasoning was wrong.

Aesop's Exemplary Use of Analogies

In contrast to Manu's and Aristotle's terrible and fallacious arguments by analogy, consider some exemplary use of "argument by analogy" by "the Storyteller from Samos", i.e., Aesop. First, though, consider a little about Aesop – if he ever existed!

During Aristotle's lifetime, according to a great little article by Donna L. Preble entitled "The Storyteller from Samos" (which I've referenced before, which you can find on the internet, and which is from the March 1975 edition of *Sunrise* magazine), the sculptor Lysippus was commissioned to

produce statues of the greatest men of Greece, and along with the statues of the Seven Sages, Lysippus included a statue of Aesop, who had been a slave when he lived on the Greek island of Samos. I'll quote a little more from this excellent article by Preble:

> Some modem scholars claim that Aesop never lived at all, that the Greeks invented him. It is true that what we 'know' of him is fragmentary. No doubt there is much legend in it. But even if Aesop never lived, the fact remains that the ancient Greeks believed he did. Thus the events and circumstances alleged about his life, whether real or fictional, hold symbolical significance – as with the life of any man enhanced by myth.

That is, Dear, even if Aesop never lived, the stories about him should have stimulated Aristotle to at least question the validity of his argument "justifying" slavery to be appropriate for people without "principles" – because maybe no one in the history of the world identified more "sound principles" than Aesop!

For example, even one of Aesop's fables about slavery could have demonstrated to Aristotle a more appropriate use of an analogy. Aristotle, in his rationalization, attempted to justify his prejudice about slavery through an "argument by analogy" (probably not realizing that such arguments can never prove that anything is "true"). Meanwhile, in the following fable (from www.classics.mit.edu), Aesop demonstrates an appropriate use of analogy: to stimulate thought.

> **Aesop: The Horse and the Stag**
> At one time the Horse had the plain entirely to himself. Then a Stag intruded into his domain and shared his pasture. The Horse, desiring to revenge himself on the stranger, asked a man if he were willing to help him in punishing the Stag. The man replied that if the Horse would receive a bit in his mouth and agree to carry him, he would contrive effective weapons against the Stag. The Horse consented and allowed the man to mount him. From that hour he found that instead of obtaining revenge on the Stag, he had enslaved himself to the service of man.

As you know, Aesop ended many of his fables with an explicit statement of the moral of the story, but in this example, he left the listener or reader to infer the moral. For example, from this fable, maybe you might infer something similar to the idea: One cause of slavery is entering into a foolish bargain with someone more cunning.

Which then makes me want to wander for a while. Dear, I wish that sometime you'd take the time to read and think about all of Aesop's fables. You can find them at www.classics.mit.edu.[5] Of course it's not known how many of these fables Aesop created *versus* how many he retold or were later added to his collection, but such details are totally irrelevant. What's relevant is not only the morals of Aesop's stories but also the stunning brilliance of "the Aesop method" by which "common folk" conveyed "moral messages" – or, they might be called, "general [scientific!] principles" – or, plain and simple, "just" wisdom.

And notice, Dear, that the moral messages in Aesop's fables aren't buried in some supernatural jabberwocky, with all the implicit and explicit threats from the gods (aka the clerics). Instead, the wisdom is conveyed in entertaining stories about animals, insects, and vegetation, which any child can imagine can talk. Let me summarize my position this way: I am absolutely convinced that humanity would take a huge leap forward if all "holy books" in the world were exchanged for copies of Aesop's book of fables! I'd even be willing to trade much of what Aristotle wrote for a chosen few of Aesop's fables.

For example, certainly I'd be willing to exchange all of the "logic" in Aristotle's foolish "justification" for slavery with the following fable about reasoning from the ex-slave Aesop.

> ***Aesop: The Wolf and the Lamb***
> Wolf, meeting with a Lamb astray from the fold, resolved not to lay violent hands on him, but to find some plea to justify to the Lamb the Wolf's right to eat him. He thus addressed him: "Sirrah, last year you grossly insulted me." "Indeed," bleated the Lamb in a mournful tone of voice, "I was not then born." Then said the Wolf, "You feed in my pasture." "No, good sir," replied the Lamb, "I have not yet tasted grass." Again said the Wolf, "You drink of my well." "No," exclaimed the Lamb, "I never yet drank water, for as yet my mother's milk is both food and drink to me." Upon which the Wolf seized him and ate him up, saying, "Well! I won't remain supperless, even though you refute every one of my imputations."

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[5] The full URL is http://classics.mit.edu//Aesop/fab.html. As presented, the fables were translated by George Fyler Townsend. Appended to Aesop Fables is the copyright statement: "The Internet Classics Archive by Daniel C. Stevenson, Web Atomics. World Wide Web presentation is copyright (C) 1994-1998, Daniel C. Stevenson, Web Atomics. All rights reserved under international and pan-American copyright conventions, including the right of reproduction in whole or in part in any form." But surely no court would penalize me for quoting Aesop, when the slave of Samos freely gave his fables to all humanity more than 2500 years ago!

Which Aesop ends with the wisdom in his moral: *The tyrant will always find a pretext for his tyranny.* Alternatively, this fable could be used to warn about how tyrants apply their damnable "principles": "My mind's made up; don't confuse me with facts" and "Who gives a damn about the data; my rationalization is right"!

To see an appropriate use of analogy (in contrast to Aristotle's use of reasoning by analogy to "justify" slavery), consider the following fable.

> **Aesop: The Man, the Horse, the Ox, and the Dog**
> A Horse, Ox, and Dog, driven to great straits by the cold, sought shelter and protection from Man. He received them kindly, lighted a fire, and warmed them. He let the Horse make free with his oats, gave the Ox an abundance of hay, and fed the Dog with meat from his own table. Grateful for these favors, the animals determined to repay him to the best of their ability. For this purpose, they divided the term of his life between them, and each endowed one portion of it with the qualities which chiefly characterized himself. The Horse chose his earliest years and gave them his own attributes: hence every man in his youth is impetuous, headstrong, and obstinate in maintaining his own opinion. The Ox took under his patronage the next term of life, and therefore man in his middle age is fond of work, devoted to labor, and resolute to amass wealth and to husband his resources. The end of life was reserved for the Dog, wherefore the old man is often snappish, irritable, hard to please, and selfish, tolerant only of his own household, but averse to strangers and to all who do not administer to his comfort or to his necessities.

Now, surely no one thinks that Aesop was attempting to argue by analogy to identify causes of common characteristics of people during different periods of their lives, but on the other hand, surely everyone is impressed with Aesop's ability to convey his ideas of these common characteristics, so forcefully, by analogy.

And of course, much additional data were available, beyond the brilliance of the ex-slave Aesop, that could have demonstrated to Aristotle that his argument (by analogy) was wrong. Thus, almost everywhere he looked, Aristotle could have seen that "natural order" wasn't the reason for slavery; instead, clearly the cause was the evil of ignorance plus power. As Socrates said (i.e., his teacher's, Plato's, teacher):

> There is only one good, knowledge, and one evil, ignorance.

In particular, Aristotle neglected to see the ignorance (and therefore evil) of promoting a morality that didn't recognize that everyone has an equal right to claim one's own existence.

I assume that when the Greeks became the slaves of the Romans, then the Greeks finally realized the immorality of slavery: that it was based solely on the law of the jungle, "might makes right", a concept that Aesop conveyed as follows.

> **Aesop: The Wild Ass and the Lion**
> A Wild Ass and a Lion entered into an alliance so that they might capture the beasts of the forest with greater ease. The Lion agreed to assist the Wild Ass with his strength, while the Wild Ass gave the Lion the benefit of his greater speed. When they had taken as many beasts as their necessities required, the Lion undertook to distribute the prey, and for this purpose divided it into three shares. "I will take the first share," he said, "because I am King, and the second share, as a partner with you in the chase, and the third share (believe me) will be a source of great evil to you, unless you willingly resign it to me, and set off as fast as you can."

And the moral of my story, Dear, is that the scientific method doesn't end with formulating some hypothesis (or creating some model): as I'll try to show you in later chapters (e.g., in the next four chapters dealing with "truth", "understanding", "values", and "wisdom") formulating a hypothesis (or building a model) is where the process really starts! Where it leads, we hope, is to wisdom – such as the wisdom conveyed by Aesop.

But that's enough of my story for now. Time to take a break – and:

If you're wise, you'd exercise!