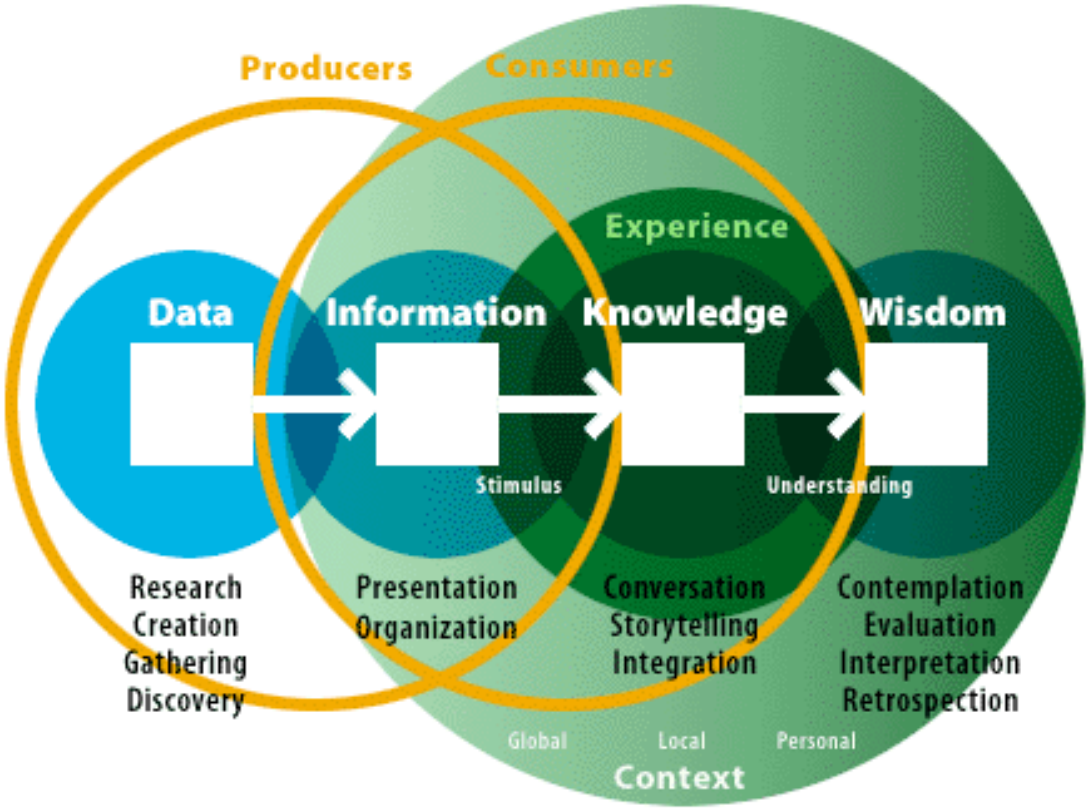
T2 – Towards "Truth" & Understanding

Dear: In this chapter, I want to move on to the topic Shedroff labeled as "Understanding" (his label on the arrow between "Knowledge" and "Wisdom") in his figure, shown again below.[1]



In the previous chapter (entitled *Towards "Truth" and Knowledge*), I tried to show you that the territory in the above "map" labeled "Knowledge" is more complicated than the map suggests. In this chapter (entitled *Towards "Truth" and Understanding*), I'll suggest that, similarly, the concept of "Understanding" can be quite complicated. Both cases therefore support the wisdom in the common expression: "The map is not the territory!"

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[1] Copied from http://www.nathan.com/thoughts/unified/index.html. The figure is contained in an article by Nathan Shedroff entitled "Information Interaction Design: A Unified Field Theory of Design."

The fundamental complication that I began to address in the previous chapter is how to determine if some knowledge is "true". I tried to show you that nothing dealing with the open system called "reality" could be known with certainty – including that statement! [That is, the previous sentence should be revised to: "In reality and almost certainly, nothing can be known with certainty."] I also tried to show you that, insofar as any statement is "true", it doesn't deal with reality.

In this chapter, similarly, the fundamental complications that I want to address are: If through experience with some information (e.g., about when the Sun rises) we claim some knowledge (e.g., that the Sun rises each morning), then how can we gain understanding associated with that knowledge (e.g., why the Sun comes up every morning) and how can we determine if that understanding is "true"?

A succinct answer to those questions is that understanding is gained *via* the scientific method. Less pithy answers are that we gain understanding any way we can (!) and that the only known way to test for the probability of the "truth" of any hypothesis is *via* Bayes' method. To try to answer the questions more informatively will require the rest of this chapter. My plan is first to make a couple of general comments about all hypotheses, then show you how Bayes' method provides a formulation for how to use evidence to estimate the probability that any hypothesis is "true", next try to show you the distinction between hypotheses about information *versus* understanding, and finally show you how such ideas have been used to generate scientific principles and theories.

I'll start, then, with two general comments about all hypotheses. Specifically, although it's correct that the *sine qua non* of the scientific method is experimentally testing predictions of hypotheses and although it's correct that understanding gained is contained in "falsifiable hypotheses not yet falsified", yet in reality, progress toward understanding isn't normally made by testing predictions of every conceivable falsifiable hypothesis. Also, falsifying any hypothesis isn't nearly so "cut and dried" as many authors suggest.

With respect to my first point (that we don't test every conceivable hypothesis), I expect that you agree, based on your own experiences. If you have a headache, for example, the cause could be that you're having a brain

hemorrhage (in which case you should call 911 to get an ambulance to rush you to the hospital), but before you investigated that hypothesis, I suspect that you'd test the hypothesis that your headache was caused, for example, by eye strain from too much studying – in which case a reasonable test of your hypothesis would be to take a couple of aspirins and a break.

In other areas of science (besides applications of science in your daily life), if we did test every conceivable hypothesis, then scientific progress would proceed at a snail's pace – or even grind to a halt – because there are so many such hypotheses. I doubt if anyone has ever tried to count all the falsifiable hypotheses not yet tested, but I'd bet there are billions of them – including such silliness as the hypothesis that this computer could type the next sentence by itself. [Guess what: it didn't – yet.] Instead, in reality, we're guided (in the choice of hypotheses to test) not only by various "needs" (and therefore "values", which I'll get to in the **V**-chapter) but also by various probability estimates, e.g., *a priori* (viz., before the fact) informed estimates ("guesstimates") of the probability that specific hypotheses are at least approaching the truth.

Feynman (co-winner of the Nobel Prize in Physics in Physics in 1965, the year I attended one of his public lectures ☺) gave a good example.[2]

> Some years ago I had a conversation with a layman about flying saucers – because I am scientific, I know all about flying saucers! I said, "I don't think there are flying saucers." So my antagonist said, "Is it impossible that there are flying saucers? Can you prove that it's impossible?" "No", I said, "I can't prove it's impossible. It's just very unlikely." At that he said, "You aren't very scientific. If you can't prove it's impossible, then how can you say what's more likely and what's less likely?" But that's the way that IS scientific. It's scientific only to say what's more likely and what's less likely, and not to be proving all the time the possible and impossible. To define what I mean, I might have said to him, "Listen, I mean that from my knowledge of the world that I see around me, I think that it's much more likely that the reports of flying saucers are the results of the known irrational characteristics of terrestrial intelligence than of the unknown rational efforts of extra-terrestrial intelligence." It's just more likely; that's all.

Stated differently, although Popper's Principle is sound ("all knowledge is contained in refutable hypotheses not yet refuted") and although Xenophanes' summary is "right on" ("all is but woven web of guesses"), yet

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[2] Copied from the report by Giulio d'Agostini of the University of Rome entitled *Bayesian Reasoning in Physics: Principles and Applications*, available at http://public.lanl.gov/kmh/course/bayesian.html; originally published as CERN Yellow Report 99-03, July 1999 (vi + 175 pages).

reasonable people proceed, not just by "guessing", but by estimating probabilities (as best they can) and then betting on the best gamble.

As an example of my second point (that "falsifying" any hypothesis isn't nearly so "cut and dried" as many authors suggest), consider the following statement [to which I've added some notes in brackets], which was made by Stephen Hawking in his 1988 book *A Brief History of Time.*

> Any physical theory is always provisional, in the sense that it is only a hypothesis: you can never prove it. [That, as near as we can tell, is correct.] No matter how many times the results of experiments agree with some theory, you can never be sure that the next time the result will not contradict the theory. [Again, that seems to be correct.] On the other hand, you can disprove a theory by finding even a single observation that disagrees with the predictions of the theory… [That depends on what is meant by "disprove": certainly it's an overstatement of "the truth" to suggest that it's simple to prove that a hypothesis is "false"; in reality, it's just as difficult to demonstrate that a hypothesis is "false" as to demonstrate that it's "true"!] Each time new experiments are observed to agree with the predictions the theory survives, and our confidence in it is increased [or more accurately, our estimate for the probability that it's true increases toward unity]; but if ever a new observation is found to disagree, we have to abandon or modify it. [That's definitely an overstatement. In reality, "if ever a new observation is found to disagree (with a hypothesis)", then the result just decreases the probability that it's true. Therefore, don't abandon it – yet!]

Now, Dear, if Hawking were the only scientist who made such a statement in writing "for the masses", I'd probably "let it pass". Unfortunately, however, the ideas he expressed are quite common among scientists (including, of course, scientists who are not so famous as Hawking). Therefore, if you're to gain some appreciation of "truth" and understanding from these chapters, I think I should spend a little time trying to make sure that you recognize his misstatements – so you won't make them yourself!

A two-word rejoinder to Hawking's incorrect statement (that "you can disprove a theory by finding even a single observation that disagrees with the predictions of the theory…") is: "It depends!" In a little more detail: "It depends on what's meant by 'theory', what's meant by 'disprove', and on details of the hypothesis under investigation." I'll try to explain what I mean using a couple of examples.

In my first example, suppose the hypothesis under investigation was the "sweeping generalization": *All swans are white*. Hawking is right in saying: "No matter how many times the results of experiments agree with some

theory, you can never be sure that the next time the result will not contradict the theory." But then he writes: "On the other hand, you can disprove a theory by finding even a single observation [underlining added] that disagrees with the predictions of the theory…"

Really, Dear? If the hypothesis "All swans are white" was your own "pet theory", which you had invested a lot of effort concocting, then would you agree that finding a single black swan would "disprove" your theory? Wouldn't you want more than a single observation? Wouldn't you want to determine if some rival had painted or dyed a white swan black?!

Yet, defending Hawking's statement, I could say that your hypothesis "All swans are white" is not really a "theory". In reality, it was simply a claim of knowledge about some data set. It didn't display any understanding about why all swans might be white nor did it make any predictions (beyond the claim that the next swan found would also be white).

But then, one should also ask what Hawking means by "disprove"? Does 'disprove" mean that the probability that your hypothesis (that all swans are white) is true has now fallen from near unity to *exactly zero*, meaning that your hypothesis is now definitely false? But how could that be? If people can't prove even that they exist to better than about 1 part in 10^{25} (we all might be simulations in some humongous computer game), then how could anyone possibly obtain an even more definitive estimate for the probability that a black swan exists?

That is, Dear, even for a hypothesis that's as sweeping a generalization as "All swans are white" isn't "disproved" by finding a single black swan; instead, the probability that the hypothesis is true "simply" falls dramatically, say from 0.999999 (when a million swans sampled were all found to be white) to, maybe, 0.5 (when your rival reported finding a black swan) to maybe 0.00001 (upon your hearing reports of several black swans being sighted) and maybe to 0.0000000000001 when you travel to Australia and find that black swans are common "with approximately 50,000 of them found at a single site"!

But the above was an example in which the probability that the hypothesis was true did fall dramatically (so, maybe it fits within Hawking's definition for his word "disprove"); therefore, now consider another example. For this example, suppose your hypothesis was the generalization: *I exist.* Suppose,

further, that you found so much evidence to support your hypothesis you claimed it deserved to be called a "general principle" and, even, that you found your principle capable of explaining so much, you decided to call it your "existence theory."

Now, Dear, although it may be painful, please recall the time you went to "that party" and a "certain someone" treated you as if you didn't exist. For that case, would you agree with Hawking that "you can disprove a theory by finding even a single observation that disagrees with the predictions of the theory…" and "if ever a new observation is found to disagree, we have to abandon or modify it"?! I doubt it! Rather, I think you would conclude that the person who made the "single observation" was a nut.

But such subjective assessments aside, an objective method is available to revise the probability of the truth of any hypotheses based on new evidence, namely, Bayes' method. That is, although it seems to be "true" that, when we gain some knowledge and even when we claim understanding of that knowledge, yet we can never be sure we've found "the truth" (we can only approach it asymptotically); nonetheless, in reality, the method of approaching "truth" needn't be so crude as you might have surmised from the previous chapter. Instead, Bayes' method provides a quantitative and relatively simple method for revising probabilities based on new evidence.

Below, for two main reasons, I want to show you a few details about how to use Bayes' method – even though you might complain that it's "too mathematical!" One reason is because Bayes' method is actually both quite simple and important. Thus, some educators argue that Bayes' method should be taught to all high-school students, because for one and as I showed you in an earlier chapter (**Ih**, entitled "Hypotheses, Probabilities, and Evidence"), it's actually the method people use (albeit, unknowingly) to decide on the guilt or innocence of the accused in any jury trial. And another reason that I want to show you a few of the details of Bayes' method (more to the point of these "science chapters") is because it's a mathematical description (and, as far as I know, the only mathematical description) of the scientific method. Besides, Dear, the math manipulations aren't important: the results are – and I'll graph them. So, please, focus on the plots that I'll provide.

In general, if there are competing, testable hypothesis that initially seem to be roughly equally plausible (i.e., all of which have comparable *a priori* =

"before the fact" estimates for the probability of being valid), then the standard procedure is to test all of them – and even more of them, if none of your first choices seems to be right! In the process, Bayes' method provides an estimate for the revised probable validity of each hypothesis, $\mathcal{H}$, based on relevant experimental evidence, $\mathcal{E}$. In the **Ih**-chapter, I tried to show you that Bayes' method can be used to make inferences from results obtained during repeated trials. Again I would suggest that the method and its mathematical formulation are simple – the only complications being derived from (i) forgetting that the method is simple (☹) and from (ii) forgetting how to read the vertical-line symbol, " | " .

As Eliezer Yudkowsky points out,[3] if like most "Westerners" you read "from left to right", then "A|B" is read "A given B"; on the other hand, if you read from "right to left" (as in the Hebrew and Arabic languages), then A|B is read "B implies A". For example, in the case of repeated trials, then in A|B, if B represents the assumed-known results from the first (n – 1) "experiments" (or "trials"), then A would represent the results to be inferred for the current, n^{th} experiment. Reading A|B alternatively, we want the probability of A given B.

But whichever way you read "A|B", Bayes' theorem (or formula) is derived from the definition of "compound" (or "joint") probabilities, i.e., the probability of something occurring (or being true) AND something else occurring (or being true), as in repeated trials. The general rule (which, as I mentioned in Chapter **Ih**, can be derived from basic axioms of probability theory but which, I encouraged you to see, is obvious – if you think about the answer for a while) is that for any two events (or propositions) A and B, the joint probability p(A&B) [or written p(AB)] can be calculated either *via*

$$p(A\&B) = p(A|B) \bullet p(B) \text{ , or } \textit{via}$$

$$p(A\&B) = p(B|A) \bullet p(A) \text{ .}$$

Equating the above two, equivalent expressions for the joint probability of A and B, p(A&B), and dividing the result by p(B) – provided it's not zero – the result is Bayes' theorem (or formula):

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[3] See his article entitled "An Intuitive Explanation of Bayesian Reasoning: Bayes' Theorem for the curious and bewildered; an excruciatingly gentle introduction", available at http://yudkowsky.net/bayes/bayes.html.

$$p(A|B) = \{p(B|A) / p(A)\} \bullet p(B) . \quad [1]$$

And if you wonder how such a "silly little result" as Equation [1] can be so important (even that it contains a mathematical formulation of the scientific method!), then you can satisfy your curiosity by working some examples.

In Chapter **Ih**, I showed you an example of using Bayes' theorem to infer the probability that your "friend" was cheating you (into your paying for her lunch on numerous occasions): after her winning a coin toss (n – 1) times, the challenge was to infer, from evidence obtained during the n^{th} toss, the probability for the validity of your hypothesis that she was cheating – all other conditions $\mathcal{C}_i$ (such as that your "friend" was consistent in the way she "played") assumed to be constant. If you want to explore other examples, many are available at many locations on the internet, e.g., you might want to start at the Wikipedia article on Bayes' theorem;[4] also, I expect that you'd find an article recently posted on the web by Eliezer Yudkowsky (already referenced) to be highly readable – and informative.

Here, however, I don't want to go into such details again. Instead, let me just restate (from Chapter **Ih**) that Bayes' theorem gives a method to estimate the ("after the fact" or *a posteriori*) probability, p, that a hypothesis, $\mathcal{H}$, is valid, based on some new evidence, $\mathcal{E}$, assuming other conditions, $\mathcal{C}_i$, are constant [viz., $p(\mathcal{H}|\mathcal{E}, \mathcal{C}_i)$], and on your *a priori* estimate of the probable validity of your hypothesis under the same conditions *via* (from Eq. [1]):

$$p(\mathcal{H}|\mathcal{E}, \mathcal{C}_i) = [p(\mathcal{E}|\mathcal{H}, \mathcal{C}_i) / p(\mathcal{E}|\mathcal{C}_i)] \bullet p(\mathcal{H}|\mathcal{C}_i) , \quad [2]$$

in which $[p(\mathcal{E}|\mathcal{H}, \mathcal{C}_i) / p(\mathcal{E}, \mathcal{C}_i)]$, known as "the likelihood", is the ratio of the probabilities that the evidence supports your hypothesis *versus* that the evidence supports all competing hypotheses.

In particular, if you want to investigate only if some hypothesis, say $\mathcal{A}$, is either "right" or "wrong" [that is, for the case of only two competing hypotheses, either $\mathcal{A}$ or "not-$\mathcal{A}$", also written as $\neg\mathcal{A}$ (e.g., for the case illustrated in Chapter **Ih**, that your friend is either cheating or she's not cheating or, e.g., in the case of clinical trials in which one uses "controls"

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[4] Available at http://en.wikipedia.org/wiki/Bayes'_theorem).

such as placebos to try to eliminate other causes)], then suppressing the notation for the "other conditions", $\mathcal{C}_i$, Bayes' formula becomes

$$p(\mathcal{A}|\mathcal{E}) = [p(\mathcal{E}|\mathcal{A}) / \{p(\mathcal{E}|\mathcal{A}) \bullet p(\mathcal{A}) + p(\mathcal{E}|\neg\mathcal{A}) \bullet p(\neg\mathcal{A})\}] \bullet p(\mathcal{A}) . \quad [3]$$

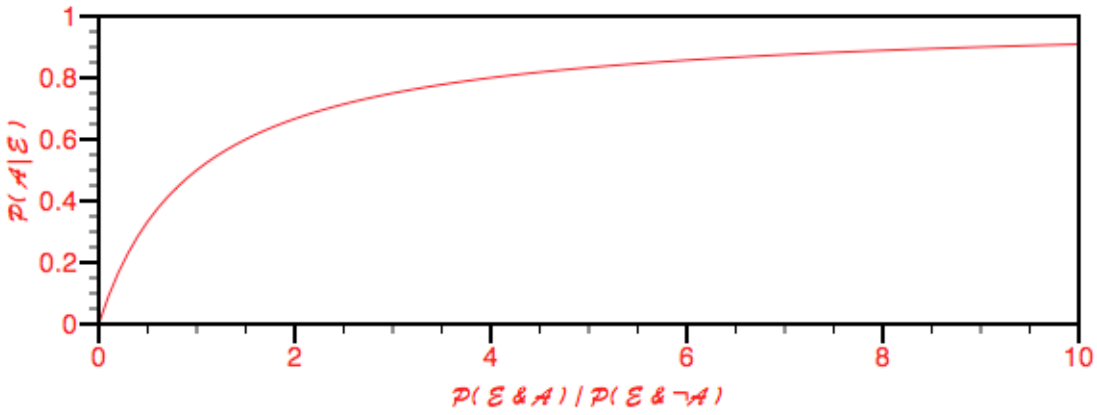
With a few more mathematical manipulations, this result can be put in a more transparent form. To that end, notice that Eq. [3] can be written as

$$p(\mathcal{A}|\mathcal{E}) = p(\mathcal{E} \,\&\, \mathcal{A}) / \{p(\mathcal{E} \,\&\, \mathcal{A}) + p(\mathcal{E} \,\&\, \neg\mathcal{A})\} . \quad [4]$$

Then, if the numerator and denominator of Eq. [4] are divided by $p(\mathcal{E} \,\&\, \neg\mathcal{A})$, Eq. [3] becomes

$$p(\mathcal{A}|\mathcal{E}) = \mathbf{x} / (1 + \mathbf{x}) , \quad [5]$$

in which $\mathbf{x} = p(\mathcal{E} \,\&\, \mathcal{A}) / p(\mathcal{E} \,\&\, \neg\mathcal{A})$. The result is plotted below. [5]



Although I've not seen the above plot published elsewhere, I think it's important, because it shows how Bayes' theorem provides a generalization for Popper's falsification principle. To see what I mean, notice the following four features of the above graph.

1. For large x-values [when $x/(1+x) \rightarrow 1 - 1/x$], i.e., when the joint probability that the new evidence & your hypothesis based on previous experiments [viz., $p(\mathcal{E} \,\&\, \mathcal{A})$] is "true" (or that the two are "compatible") is large compared with $p(\mathcal{E} \,\&\, \neg\mathcal{A})$, i.e., the joint probability that the evidence and the antithesis of your hypothesis is "true" (or

[5] Generated with thanks to the application's creator, Michael Wasemann; the application "Plot" is available for Mac computers at http://plot.micw.eu/Main/HomePage.

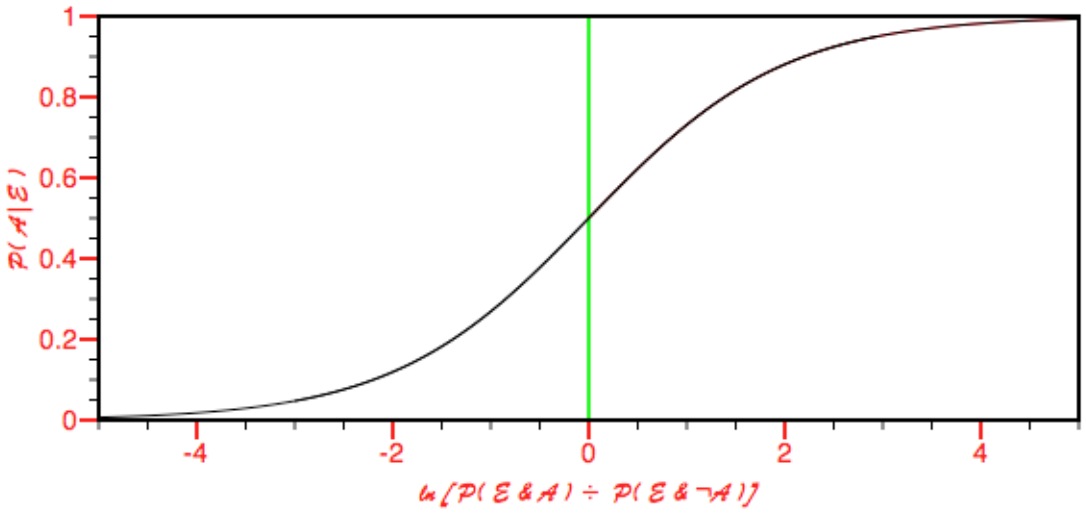
that the evidence and your hypothesis are incompatible) – or stated more simply and for the case when you're trying to determine if your "friend" is cheating: when the evidence is much more compatible with your hypothesis that she's cheating than with the antithesis that she's honest – then as shown at the right-hand side of the graph, the probability of your hypothesis being true, given the new evidence, slowly climbs toward unity (i.e., "certainty") – although it only climbs toward unity asymptotically, never making it all the way to "certainty", no matter how strong the evidence.

2. For x = 1, that is, if the joint probability for the evidence and your hypothesis is the same as for the evidence and the negation of your hypothesis (which is a long-winded way of saying that, before obtaining the new evidence, you don't have a clue if your hypothesis is right), then when the new evidence is in, $p(\mathcal{A}|\mathcal{E}) = 1/(1+1) = ½$, which says that the new evidence also doesn't help you: you still won't have a clue if your hypothesis is "true" vs. "false" (which, by the way, is one way of saying that the entropy is a maximum, meaning you have no knowledge about the system).

3. For small x-values [when $x/(1+x) \rightarrow x$)], i.e., when the joint probability that the evidence & your hypothesis is "true" is small compared with the joint probability that your evidence and your hypothesis are incompatible (or more simply, when the evidence is much more compatible with the antithesis of your hypothesis than with your hypothesis) – or again, for the example worked in **Ih**, when the evidence strongly suggests that she isn't cheating (i.e., that she's honest) – then as shown at the left-hand side of the graph, the probability of your hypothesis being true (e.g., that she's cheating), given the evidence, falls toward zero. Thereby, you don't immediately "disprove" your hypothesis (as Hawking stated), but you find additional support for the idea that your hypothesis is in major trouble.

4. There is, nonetheless, a symmetry between the cases of verification (large x) and falsification (small x) of your hypothesis, in that, for example, for the cases of x = 10 and 100, the probability that your hypothesis is true, $p(\mathcal{A}|\mathcal{E})$, will be 0.9 and 0.99, respectively, whereas in the cases of x = 0.1 and 0.01, $p(\mathcal{A}|\mathcal{E})$ will be 0.1 and 0.01, respectively. That is, for example, if the evidence is 100 times more compatible with your hypothesis than its antithesis, then the evidence confirms your hypothesis to within 1%, but at the other extreme, if the antithesis of your hypothesis is 100 times more compatible with the evidence, then to within 1% probability, you can conclude that your hypothesis is wrong.

That the asymmetry in the above plot is derived from the math and not "reality" can be seen by changing the variable for the abscissa from x to $\xi = \ln x$ (i.e., $x = e^{\xi}$). The result is shown below – in fact, if you work at it for a bit [starting from the definition of the odds associated with any probability: $O = p/(1 - p)$, so $\lg\{O(\mathcal{A})\} = \lg\{p(\mathcal{A})\} - \lg\{p(\neg\mathcal{A})\}$, where lg is logarithm using any base], then you can see that the abscissa is the logarithm of the odds, i.e., $\lg\{O(\mathcal{A}|\mathcal{E})\} = \lg\{p(\mathcal{E}\,\&\,\mathcal{A})\} - \lg\{p(\mathcal{E}\,\&\,\neg\mathcal{A})\}$; therefore, that's how to revise odds based on new evidence, as in the jury trial in Chapter **Ih**.



From the above plots, Dear, I hope you see not only the math behind Popper's falsification principle and a better interpretation of what Hawking was trying to say but also, and more importantly, the math behind the scientific method. As Yudkowsky states in his on-line article:[6]

> To increase the probability of a theory you *must* expose it to tests that can potentially decrease its probability [of being valid]; this is not just a rule for detecting would-be cheaters in the social process of science, but a consequence of Bayesian probability theory… Bayes' Theorem shows that falsification is *very strong* evidence compared to confirmation, but falsification is still probabilistic in nature; it is not governed by fundamentally different rules from confirmation… So we find that… the statistical methods used by scientists, plus the scientific method itself, are all turning out to be special cases of Bayes' Theorem…

And actually, Dear, since the same analysis is appropriate for any set of evidence used to test the validity of any hypothesis, the above math suggests that there's psychological bias in "folklore wisdom" such as: it's easier to displease people than please them, it's easier to lose trust than gain it, or it's easier to lose friends than gain them. In reality, they're the same: as shown in the above plots, verification and falsification are mathematically similar at large and small x-values. Maybe the cause of such "psychological bias" is that normally we're not very interested in the difference between when a person can be trusted, say, for 1% vs. 10% of the time: when trust drops below, say, 99%, we're "on guard" against their trickery – which is usually wise!

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6 Quoted from http://yudkowsky.net/bayes/bayes.html.

Meanwhile, Dear, if there were too many symbols in the above formulation to make it easy to follow, then you might be pleased to recall the summary by Pierre-Simon Laplace (1749–1827): "The theory of probabilities is at bottom nothing but common sense reduced to calculations." Consequently, to determine if you've developed some useful hypotheses, then fortunately, it's adequate "just" to apply your common sense – including the "common sense" to realize that, in reality and almost certainly, nothing can be known with certainty. That is, in reality, the best that most people can do is "just" use common sense to identify and then "muddle by" with some "useful working hypothesis" – never clinging to any of them more strongly than relevant evidence warrants.

Thereby (and extremely fortunately for the rest of us dolts), many brilliant humans (too numerous to list) have discovered some astoundingly "useful working hypotheses". Before commenting on some of their hypotheses, however, I want to try to ensure that you appreciate the distinction between 'knowledge' and 'understanding', as well as begin to appreciate what's meant by "scientific principle" and what's required for something to reach the status of "scientific theory." Fortunately for me, such ideas were aired quite clearly during a conversation between a certain grandfather and a certain grandchild (GC#3), a conversation that evolved roughly as follows.

"Grampa!"

"Yes, Dear."

"I just made an amazing discovery!"

"That's my grandchild! And what was it?"

"The Sun comes up every morning!"

"Wow! No doubt you'll get a Nobel Prize for that one. But tell me: how do you know the Sun comes up every morning?"

"Logical induction."

"Really? I thought Hume and Popper said there was no such thing as 'logical induction'."

"Whatever."

"Well, come on – tell me how you figured it out."

"Okay, if you're gonna get sticky about it: from the data I've been keeping."

"You mean: your data show some temporal regularity, and from that regularity you claim the knowledge that the Sun rises each morning?"

"Right."

"And how do you know that your knowledge is 'right'? How do you know it's 'true'?"

"Picky, picky! Okay, based on my many years of data, I claim that my knowledge (that the Sun comes up each morning) has at least a 99.99% chance of being 'true'."

"Well, that's pretty impressive, kid – but tell me: "Why does the Sun come up each morning?"

"Ha! I've also figured that out: it's because the Earth spins."

"Wow! No doubt, you'll get your second Nobel Prize for that hypothesis – but tell me, how did you reach your understanding that the Earth spins? I mean, the Bible and the Quran state that the Sun comes up every morning because the Sun travels around the (flat-plate) Earth."

"Well, yes, that's how it was understood a long time ago, but I'm saying that the understanding of the primitive authors of those books wasn't true: ever since the first sailors 'circumnavigated the globe', it's been known that the Earth is more like a ball than a flat plate."

"Okay, I can buy that – but even if it's a ball, who's to say that the ball isn't sitting still and that the Sun, Moon, stars, and stuff go around the Earth?"

"Me!"

"Huh?"

"I'm saying that it's not the Sun and stuff that go around a stationary Earth, but that the Earth spins – and people just think that the Sun moves, cause they're standing on a spinning ball!"

"Well, sorry, Dear, but who are you to say that the Earth spins? *Psalm 104,* 1–5 of the Holy Bible says:

> *Praise the LORD, O my soul. O LORD my God, you are very great; you are clothed with splendor and majesty. He wraps himself in light as with a garment;*

> *he stretches out the heavens like a tent and lays the beams of his upper chambers on their waters. He makes the clouds his chariot and rides on the wings of the wind. He makes winds his messengers, flames of fire his servants. He set the earth on its foundations;* ***it can never be moved.***

“Grampa, get with the program. The Bible was written by people who didn’t understand stuff. They just guessed.”

“And isn’t this hypothesis of yours, about the Earth spinning, just a guess? How else did you reach your claimed understanding?”

“It just came to me.”

“Riiiiight. And tell me, little one: what’s the chance that this understanding of yours is correct or ‘true’?”

“Well, it works, doesn’t it?”

“Yah, sure – but it doesn’t work any better than the idea that the Sun and stuff go around the Earth!”

“So – I like my idea better.”

“I can believe that – but tell me: does your claimed understanding for why the Sun comes up every morning (namely, your hypothesis that the Earth spins) provide any ideas or predictions different from those of the hypothesis that the Earth is stationary and stuff goes around it?”

“Yup.”

“Like what?”

“Like the winds.”

“Whaddya mean?”

“Well, think about it: what causes the winds?”

“Well, I’m not sure, but I’ve heard that they’re caused by the wind god, Woden, whom we honor every Wednesday, that is, Woden’s day.”

“Grampa!”

“Oh, sorry, my mistake: I forgot that you were taught to believe that it was a different god who rules the winds. So, then, in the Bible, *Psalm 135,* 5–7 says:

> *I know that the LORD is great, that our Lord is greater than all gods. The LORD does whatever pleases him, in the heavens and on the earth, in the seas and all their depths.* ***He makes clouds rise from the ends of the earth; he sends lightning with the rain and brings out the wind from his storehouses.***

"In fact, that same idea is stated again in the Bible at *Jeremiah 10,* 13 and *Jeremiah 51*, 16. And for good measure, *Amos 4,* 13 gives:

> *He who forms the mountains,* ***creates the wind,*** *and reveals his thoughts to man, he who turns dawn to darkness, and treads the high places of the earth – the LORD God Almighty is his name.*

"And then, of course there's the power over the winds that Jesus reportedly had, e.g., at *Matthew 8,* 27 (and similar is at *Mark 4*, 39 and *Luke 8,* 25):

> *The men were amazed and asked, "What kind of man is this?* ***Even the winds and the waves obey him!****"*

"And also there's this at *Revelation 7*, 1:

> *After this I saw four angels standing at the four corners of the earth,* ***holding back the four winds of the earth*** *to prevent any wind from blowing on the land or on the sea or on any tree.*

"So, I'd say that, in total, the Bible makes it clear that God controls the winds."

"Grampa: you're pathetic. Forget about what the Bible says; forget about what other people say; forget about relying on authority figures; figure it out for yourself! Haven't you ever heard of Zen? Come on, now: what causes the winds?"

"Well, you're the one into Zen, rejecting Woden and the other gods; so, how about if YOU tell ME what causes the winds – at least, according to your hypothesis."

"Okay, that's easy. First: do you agree that, in a gravitational field, hot air rises?"

"Ha! One of the first things I remember well about school – I think it was in Grade 4 (60 years ago!) – was that we had to write plays or skits, and the best three were to be acted out by other kids in the class. Mine was one of them; I got to be writer, director, and producer! I still remember it; I called it "Hot Air Rises"; it was about these two bank robbers who used blowtorches to get into the vault, but when they finally got in, they didn't see any money – because it had been stored in bags hung on the inside of the vault's door, and when the thieves used their blow torches on the door, the air in the money-bags was heated, the bags rose to the top of the vault, and the robbers never looked for money on the ceiling!

"Okay, okay, grampa – don't get carried away with your old stories. The point is: you agree that hot air rises. So, do you agree that air rises at the Equator?"

"Well… yah… I suppose so… generally… it seems reasonable. On this big old ball called Earth, the surfaces at the Equator gets more direct sunlight than the surfaces at the Poles. That's why it's hotter in equatorial regions than at the Poles. So, it seems reasonable that air would rise in equatorial regions and then sink in polar regions."

"Good, grampa – there's hope for you yet! So you agree that heating the equatorial regions and cooling in polar regions would generate winds?"

"Yah, I guess so: if the air rises near the Equator and sinks near the Poles, then because 'nature abhors a vacuum', other air has to come in to fill up the vacated space. So, I guess winds would develop: upper-level wind heading north and lower-level wind completing the loop, heading south. But what's that got to do with your hypothesis that the Earth spins?"

"Patience, grandfather."

"Child… Grandfathers are supposed to say that to grandchildren; not the other way around. But anyway: I still don't see how your idea of a spinning Earth has anything to do with the winds."

"Well, look at the data."

"What data?"

"For the winds – tell me what you know about the major winds on Earth."

"Gees. What is this? I already passed my Grade 4 geography tests!"

"Grampa: just tell me. What do you know about the Trade Winds, the Doldrums, the Westerlies, the North Easterlies, and so on?"

"Okay – but don't go passing out any grades; this is from memory, from a long time ago. Trades winds: Columbus tapped into those to sail across the South Atlantic from east to west. The Doldrums: if you're sailing, ya gotta watch out for them, cause there's no wind; I remember from the *Rhyme of the Ancient Mariner* by Samuel Taylor Coleridge:

Day after day, day after day,
We struck, nor breath nor motion;
As idle as a painted ship
Upon a painted ocean.

"As for the Westerlies; shucks, I know them well; I grew up with them blowing. But I never lived farther North, where they say that the North Easterlies blow."

"That's fine."

"So: did I pass the exam?"

"Sure, grampa – and I liked the poetry. But tell me: do those winds make sense to you?"

"Whaddya mean: 'make sense'? Those are the winds. What's there to make sense about?"

"Well, do they agree with the ideas of hot air rising near the Equator and cool air sinking near the Poles – on a stationary Earth?"

"I don't understand."

"Well think about it: you said you grew up where the Westerlies blow."

"Yup."

"But weren't they actually more from the southwest rather than just the west?"

"Yah… usually… but they're called Westerlies."

"Okay. But does that make sense to you?"

"Again, whaddya mean: 'make sense'? Those are the winds and that's that!"

"Okay, but does it make sense that there are winds near the surface of the Earth in the Northern Hemisphere flowing from the southwest? I mean: didn't we agree that, if hot air rises at the Equator and sinks at the Poles, then the winds near the surface in the Northern Hemisphere should be flowing FROM the North?"

"Gees, kid. This is gettin' to be too much like an exam. How about you telling me if the winds make sense!"

"Okay, okay, keep your blood pressure down – but do try to keep a little blood flowing to your brain – cause what I'll show you is that the observed winds make sense ONLY if my hypothesis is right that the Earth spins."

"This I gotta hear."

"Okay. Start again at the Equator, where the heated air rises."

"So far, so good."

"As the moist air rises…"

"How come it's moist?"

"Because of evaporation of water from the oceans."

"Uh… okay."

"Anyway, as the moist air rises and cools by expansion (because the air pressure is lower at higher altitudes), then the moisture condenses in cloud drops, and there's lots of rain."

"Hmm… I guess so. I've heard that it's muggy in the Tropics and that there's lots of thunder, lightning, and rain. So you're saying that the rain is caused by moist air rising. But what's that got to do with your spinning Earth hypothesis?"

"Nothing yet – be patient. In part, I wanted to prepare you for why the upper air will be dry (because the moisture has rained out), and in part, I wanted to make sure that you didn't go off on some tangent about the rain being caused by Thor – whom you honor every Thursday, that is, Thor's day."

"Gees – I heard it was Zeus – and the Bible says it was God; remember: *He makes clouds rise from the ends of the earth; **he sends lightning with the rain** and brings out the wind from his storehouses*."

"Grampa: shhh. Now, where was I?"

"In the upper atmosphere, above the Equator, blowing hot air."

"Well, I'll skip the insult – but I'll note that at least you seem to be paying attention. So now, pay even more attention to that dry air, which is now heading toward the Poles. Focus on the air heading North."

"Gotcha. I'll pretend I'm in a balloon, floating in the upper atmosphere, heading toward the North Pole."

"Good. But guess what: you ain't gonna make it."

"Huh? Why not?"

"Well, think about it. On a spinning Earth, you started off, above the Equator, moving with the Earth (and the air) at about 1,000 mph toward the East."

"Well… yah… I guess so… **IF** you're right that the Earth spins! So what?"

"Well, if you now start floating with the air in your balloon toward the North, then the farther north you go, the slower the surface of the Earth will be moving relative to you in your balloon."

"I don't get it."

"Come on – think about it. As someone once said: 'look at the limits'. At the North Pole, how fast is the ground moving?"

"Well, if you're right that the Earth spins, then very close to the North Pole, say a foot or so away from the Pole, the ground is moving around a circle of about one foot radius in 24 hours, so it's going at about $(2\pi r) \sim 6$ feet in 24 hours so at a speed of about one quarter of a foot per hour."

"Good! And isn't that kinda slow compared with 1,000 mph?"

"Hmm, so maybe I see your point. You're saying that, if the Earth spins, then the farther I'd travel north in my balloon, riding in the upper atmosphere from the Equator, the faster I'd seem to be going toward the East compared with the ground below."

"That's what I said."

"Hmm. That's kinda neat. So you're saying that, if I get above Mexico City in my balloon (with Mexico City spinning with the Earth at, maybe, 750 mph), then someone in Mexico City looking up and seeing me in my balloon would say that I was zooming eastward at, say, 250 mph?"

"Right – but you'd probably not be going quite that fast, maybe only half that speed, because there's friction between the upper and lower air."

"Whatever. That seems to be just a wrinkle. More important is: are you right? Have you done it? Have you ever taken a ride in such a balloon?"

"No – but data are available. Weather balloons are used to track upper-level winds."

"And what do they show?"

"Come off it. Haven't you ever heard of the Equatorial Jet Stream?"

"Hmm… Yah… I suppose. Sometimes on the Weather Channel I've seen it depicted over Florida. It's a high-altitude, high-speed wind."

"Right. So what causes it?"

"You tell me!"

"Grampa. Use your head. Put the pieces together. The upper air near the Equator starts off at high speed toward the East because of the Earth's spin. Then, as the air moves poleward, it continues to move with the same eastward speed (except for losses caused by friction). Consequently, to observers fixed to the Earth below, the air seems to turn to its right (in the Northern Hemisphere; to its left, in the Southern Hemisphere). It's called the Coriolis effect."

"So you're saying that this 'Coriolis effect' and the Equatorial Jet are what?"

"Grampa. Come off it. They're proof that the Earth spins."

"Hmm… that's kinda interesting, kid. But what about the rest of the winds?"

"Well, just figure it out – taking account of the spinning Earth and the resulting Coriolis effect."

"Humor me, kid; show me what you mean."

"Okay. Pretend you're back in your balloon, now zooming Eastward in the Equatorial Jet Stream."

"Sounds like fun!"

"You'll start to sink."

"Gees… party pooper! How come?"

"Well, the longer that dry, equatorial air is up there, heading East, the cooler it'll become."

"Cause it'll radiate its energy to space?"

"Good job grampa! And when the air (including the air in your balloon) cools, then it'll get heavier and start to sink toward the surface."

"The Equatorial Jet comes to the surface?!"

"No, grampa: the Jet is continuously fed by more air from equatorial regions; but air leaves the jet, sinks, and slows down because of friction from lower air."

"Hey! I know enough about meteorology to know that when dry air sinks, then there aren't many clouds."

"Right – and as that dry air descends, its pressure increases, heating it."

"Wow! Like the Sahara Desert!

"Exactly so – as well as the generally dry areas at all such latitudes, except for places like Florida and Southeast Asia, where local winds from the oceans provide rain. And meanwhile, on the oceans, you get the Doldrums: just as Coleridge wrote in the next stanza after the one you quoted:

Water, water, everywhere,
And all the boards did shrink;
Water, water, everywhere,
Nor any drop to drink.

"Wow, kid, that's neat – but then what?"

"Well, for one: near the Earth's surface, part of the descending wind heads south, completing the loop that started with the air rising near the Equator – which, incidentally, is called the Hadley cell or the Hadley circulation."

"Whatever. The main point seems to be your suggestion that the lower-level winds would predominantly flow southward, south of the Equatorial Jet Stream."

"Yah… but actually, because of the Coriolis effect (that is, because Earth spins), then as the air moves southward, it turns to the right."

"Well I'll be damned – those are the trade winds that Columbus caught!"

"That's right."

"Neat – and what was your other point?"

"Oh – thank you – it's that some of the descending air turns south (as the Trade Winds), but some turns northward."

"How come."

"Well, think about it: as the air descends, it drags air down with it – including air that's north of the Hadley cell."

"Seems reasonable – but so what?"

"So, you can't just drag air down without some air flowing in to replace it; as you said (quoting Aristotle): 'Nature abhors a vacuum'."

"Hmm. Sounds like another circulation would start up."

"That's right. Air in the upper atmosphere north of the Equatorial Jet Stream goes southward…"

"Southward! That's opposite from the original idea that upper air would go northward."

"Right. But the data show that's what happens. And meanwhile, the loop is completed with some of the descending air traveling north near the surface (or actually, because of the Earth's spin, northeastward – what you learned to call 'the Westerlies'), then climbing in altitude (because the air is generally warmer than the local air), going faster and faster (relative to the ground below) toward the East, and eventually forming the Polar Jet Stream."

"Wow, kid, I'm impressed. That not only explains the Westerlies, but also why it rains so much in the Pacific Northwest and in Western Europe: because the warmer air, that picks up water off the oceans, climbs up over the colder, northern air."

"Yup – and to complete the picture, although some of the air near the Polar Jet Stream heads south in the upper atmosphere to complete one loop, some of it heads to the North Polar region, there sinks (carrying with it a lot of mid-latitude pollution to the Arctic), and then, the air completes that third loop, heading south (turning to the right as it does so), creating the polar North Easterlies."

"Child: again, I'm impressed. You've explained the major features of the Earth's winds (as well as some climatology) from your hypothesis that the Earth spins!"

"Yah – except I'm thinking of calling it not just my hypothesis but my theory."

"Well – go easy there, kid. Usually the term 'scientific theory' is restricted to those ideas capable of explaining a lot of stuff. And though I grant you that your hypothesis that the Earth spins explains a lot about meteorology and climatology, I wouldn't be surprised if some people would say that you're 'pushing it' to claim that it's reached the status of a 'theory'."

"Phooey! My hypothesis explains lots of other stuff."

"Like what?"

"Well… like the ocean currents."

"Whaddya mean?"

"Grampa: use your head. Why do you think that the Gulf Stream and the Japanese current turn to the right?"

"You mean that it's the same Coriolis effect caused by the Earth's spin?"

"Of course! And not only that, have you ever aimed an ICBM?"

"You mean an Inter-Continental Ballistic Missile?!"

"Yah. Have you ever aimed one?"

"Not that I recall."

"Well, if you ever do, then make sure you account for the Earth's spin, or else you'll miss your target: in the Northern Hemisphere, if you shoot northward, then aim west of the target."

"Well, I'll keep that in mind if I ever aim one – but maybe I wouldn't need to adjust my aim, if I shoot exactly East or West."

"You're catching on. Also, my theory explains why, for satellite launches, the rockets always start heading East (to take advantage of the speed from the Earth's spin), how Geostationary satellites (such as TV and weather satellites) can sit above a point on the Earth without falling (by balancing gravitational and centrifugal forces), and why Space Shuttle re-entries are from the West (again, to take advantage of the speed from the Earth's spin)."

"Impressive, kid."

"Not only that, my theory explains why Mt. Everest (with height of about 29,000 ft) is NOT the tallest mountain on Earth; instead, it's Mt. Chimborazo (height of about 20,000 feet, in Ecuador)."

"Hello? Did you just say what I think you said?"

"Yes – and I'm right. Those heights are above sea level, but because the Earth is mostly molten rock and it spins, the Earth bulges near the Equator; so, the 20,000 ft Mt. Chimborazo in the Andes is actually farther from the Earth's center and reaches farther out into space than the 30,000 ft Mt. Everest in the Himalayas."

"Wow, kid – I'm really impressed – maybe your ideas DO rank being called a 'scientific theory'. What's more, I'm thinking that you've discovered an amazingly powerful scientific principle – which can be stated in such an amazingly simple way, namely, 'The Earth spins'."

"Well, as Feynman said: 'The deeper the law… in physics, the simpler it becomes'."

"Amazing! My grandchild discovered the 'deep' scientific principle that the Earth spins, and since it all fits together so well, it could even be called a theory, maybe the 'spinning Earth theory'."

"No way!"

"Huh?"

"Well, think about it: how come there's Darwin's theory of evolution, Maxwell's electromagnetic theory, Einstein's theory of relativity, and so on, and yet you're proposing that my name isn't to be associated with my theory?!"

"Oh… sorry kid…all right. How about: 'GC#3's theory of the spinning Earth'."

"Grampa – you really don't get it, do you?"

"Oh yah. Well, just because your theory explains winds and stuff, don't think that you know everything. Remember – in the Bible at *Ecclesiastes 11,* 5 it states:

> *As you do not know the path of the wind, or how the body is formed in a mother's womb, so you cannot understand the work of God, the Maker of all things.*

"Grandfather: I know how babies are formed!"

"Oh no you don't, kid! One theory per child – that's the rule."

"No way!"

"Yes way! And don't complain to me; it's not my rule; if you don't like the rules, take it up with your grandmother; she sets all the rules. That's how I got authority to choose what oil is put in the vehicles."

"GramMA! Grampa said that I don't know how babies are formed and that you said I'm not allowed to know…"

"Don't worry, Dear – old grandfathers don't know everything – some don't even know what oil to use in different vehicles – mostly, they just know how to tease their granddaughters. Just sit down here for a while and tell me what you know about how babies are formed…"

Sorry, Dear: as you know, sometimes I get carried away. Anyway, I hope you see the difference between claimed 'knowledge' (e.g., that the Sun rises every morning) and claimed 'understanding" (e.g., because the Earth spins), and that if this understanding demonstrates substantial validity, it can be raised to the classification of a "scientific principle", with the total of the understanding and explanations described as a "scientific theory", such as the theories of evolution, mechanics, thermodynamics, electromagnetism, quantum mechanics, relativity, and so on.

And what I'd like to do now, Dear, is show you some of those scientific principles and theories that have been discovered. If fact, what I'd really like to do is show you ALL of them that humanity has so far uncovered. And actually, I did start on such an undertaking (and earlier in the book, I advertised that I would do so in an "excursion" identified as **Ux**, entitled "Uncovering Understanding"). But, Dear, I'm sorry to report that there's "no way" that I'll be able to accomplish such an undertaking – at least during this lifetime (☹). Too much is known by others, and too little time is left for me to try to learn what they understand. Consequently, I've drastically scaled back my plans for how many such principles and theories that I'll try to show you (in the "excursion" $\mathbf{Z_0x}$, entitled "Zen of Zero Exploration"): with $\mathbf{Z_0x}$, I'll focus on those scientific principles that I'll want to use in the **Z**-chapters, where my goal will be to show you how the universe might have created itself from totally nothing. Then later, when I get some "free time" (!), I'll revise the earlier chapters so that my poor planning will no longer be quite so obvious!

For the rest of this chapter, therefore, rather than try to show you a summary of scientific principle and theories, I'll try to try to show you some general features of all of them. I'll start with a proposed definition, namely, when we say that we 'understand' some thing or process, we mean that we have a "useful working hypothesis" about it, i.e., a hypothesis

1) That succinctly summarizes a substantial quantity of reliable data,

2) That's consistent with other hypotheses found to be useful,

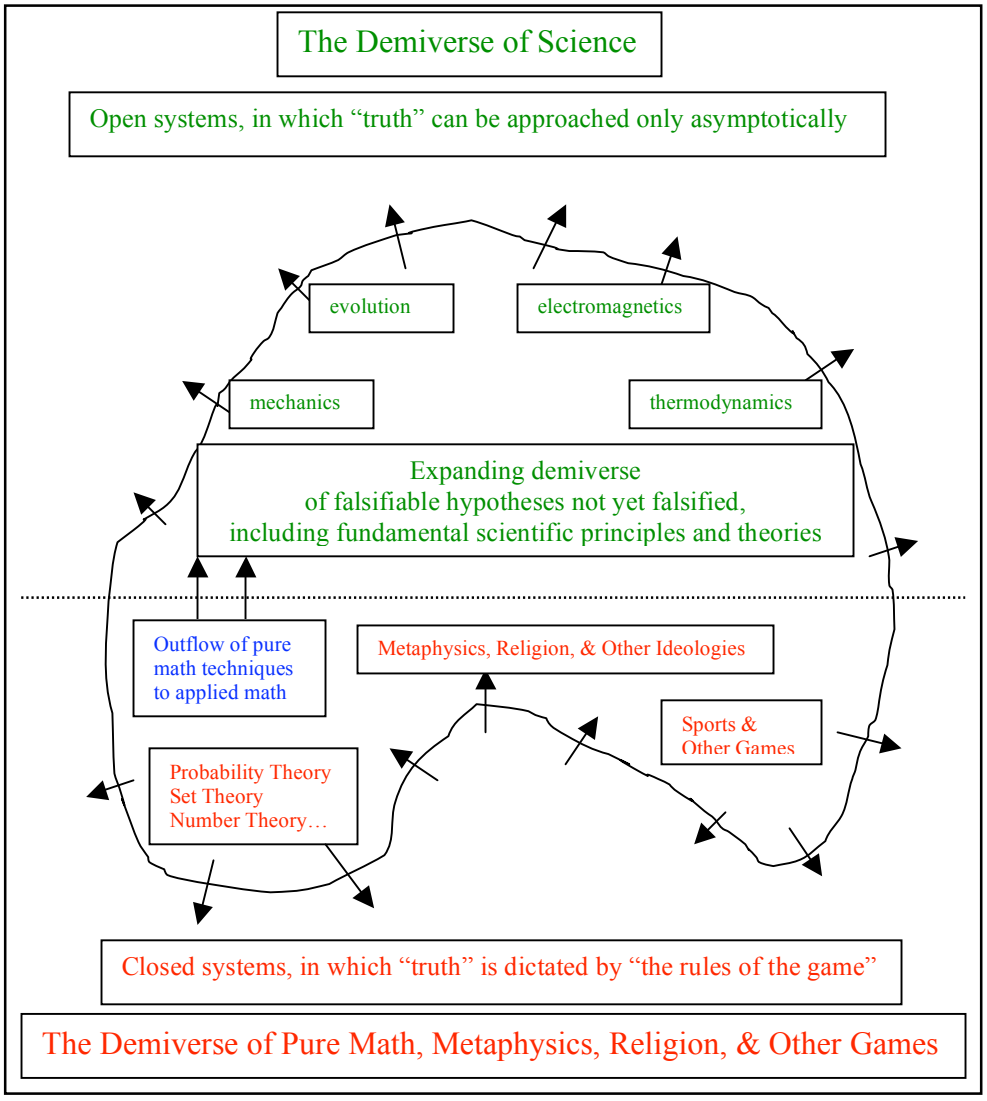
3) That can generate predictions that can be tested, and

4) For which experimental evidence suggests that the probability that the hypothesis is true is very much larger than the probability that the hypothesis is false.

And if you think it "rather pathetic" that satisfying the above criteria is all that's meant when we say that we "understand" something, Dear, then I'd tend to agree with you – but this pathetic meaning for "understanding" is far better than those (such as all clerics) who claim they know more!

From the previous chapter, recall the different meanings for "truth" in open *versus* closed systems. In closed systems (in all religions, stories, pure math, and other games), "truth" means whatever the "story line" fabricates. Such

"truth" can be trusted only so long as one stays coddled within the fabrication – as in all religions, which drug with the comforting delusion that reality is a closed system and which stupefy with a perverse use of the principle: claims that contain no information can't be demonstrated to be false. Thereby, no tests are available to eliminate religious errors. For open system, in contrast (e.g., in reality), to gain knowledge from some information (in turn derived from some data), we start with hypotheses that satisfy the criteria listed above – and for which 1) we perceive there's some "value" in developing relevant hypotheses and for which 2) our *a priori* estimate is that, of all competing hypotheses, the ones chosen for testing seem most likely to be approaching "the truth". I've tried to outline the above distinction in the sketch below.



In the above sketch, I've tried to show you some general features of the resulting "Universe of Ideas", split into a "Demiverse of Science" and a "Demiverse of Pure Math, Metaphysics, Religion, and Other Games" (in which I've used the second meaning of the prefix *demi,* i.e., 'partially'). I trust you understand what I'm trying to say with the sketch, Dear, but I should admit that a major limitation with such a schematic is that it doesn't adequately portray changes in understanding (e.g., "transitions" in ideas about "truth"). I tried to indicate such changes with all the arrows, but what I want to do, now, is try to provide you with a better idea about how ideas change – in fact, even about the idea of "change", itself.

As I've mentioned in earlier chapters, ideas governed by classical, Aristotelian logic have many, significant limitations. For example, in classical logic, statements (or "propositions") are assumed to be either true or false, but in reality, whereas it appears that we can never "prove" what's "true" (or "false"), then classic logic becomes not much more than another closed-system word-game, in which the logician basically says: "Let's play a game pretending that some statement, say ***A***, is true; then, what follows logically?" Admittedly, experience has shown that this can be a valuable game, but it shouldn't be forgotten that it's a game that depends entirely on the assumption that ***A*** is true, which in reality can't be demonstrated. Further, from the claim that *if any statement can be demonstrated to be "true", then the demonstration simultaneously shows that the statement doesn't refer to reality*, then it follows that demonstrations of "truth" via any "logic analysis" (including Aristotelian, Boolean, and most types of modern "symbolic logic") have significant limitations – an exception possibly being the logic that incorporates probabilities, namely "fuzzy logic". [7]

Another significant limitation of classical logic is that, in reality, the basic "laws" of logic can be violated. As I outlined in an earlier chapter [**Ib2**], these basic laws are 1) the law of identity or existence [$\boldsymbol{A \equiv A}$], 2) the law of noncontradiction or distinctiveness [$\boldsymbol{A \neq \neg A}$], and 3) the law of the excluded middle or uniqueness [i.e., either ***A*** or $\boldsymbol{\neg A}$]. The consequence of violating such laws can be significant.

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[7] Dear: If you want to at least glance at other types of logic (and just glance, for now, because they'd take you a lifetime of study to understand!), then see, e.g., the appendix and references of the article by Chris Lucas entitled *A Logic of Complex Values* at http://www.calresco.org/lucas/logic.htm. In addition to Classic Logic, he briefly describes logics with the adjectives Alethic Modal, Deontic, Epistemic, Temporal, Dynamic Doxastic, Proairetic, Quantum, Nonmonotonic, Fuzzy, Mereology, Non-Adjunctive, and others! And by the way, Dear, in Boolean Algebra (used in computers and in symbolic logic), the basic rules are: 0 + 0 = 1, 0 + 1 = 1, 1 + 0 = 1, and **1 + 1 = 1.**

For example, I tried to show you in the previous chapter that when, in reality, the "law" of distinctiveness is violated, then you can obtain the result that one plus one can equal one. More significant results (showing more significant limitations on classical logic) occur when (as commonly occurs in reality) the "law" of identity is violated. But to be able to show you that, Dear, I'd have to be better.

"Well, then, be better!" exclaimed a certain grandchild.

"Sorry, Dear, but Aristotle said I can't be better."

"Huh?" questioned the grandchild.

"Well, Dear, look: Aristotle said $A \equiv A$."

"So?"

"Well, then, obviously it's logically impossible for me to be better: if you accept that $A \equiv A$, then how can you possibly ask me (with a straight face) to be better, i.e., to satisfy $A \equiv \neg A$?"

"Grandfather, stop being so silly: people can change."

"Sorry, Dear, but according to Aristotle, $A \equiv A$, so change is impossible."

"Well, then," concluded the grandchild, "phooey on Aristotle."

I agree with you, Dear. The point is: all of classic logic (and, in fact, fuzzy logic, as well) deals with propositions about "stuff" fixed in time: changes (or transitions) are prohibited![8]

Restrictions of classical logic to "spatial and temporal invariance" (i.e., things aren't allowed to change) aren't significant for closed-system "games" (such as games of sport and chance, pure math, and all stories, such as all religions), because for closed systems, the propositions are independent of space and time. In them, one plus one always equals two, Superman is always weakened by kryptonite, God always rules the universe,

[8] Which reminds me, again, of Montaigne's brilliance, from 400 years ago: "Quelle vérité que ces montagnes bornent, qui est mensonge qui se tient au delà?" [What of a truth bounded by these mountains that's false to the world outside?] Thereby, he acknowledged the possibility that "truth" can change: A may equal A here and now, but maybe not somewhere else or some other time.

and so on. In fact, a dominant feature of most religions (especially "fundamentalist" religions such as most Islamic and many Christian sects) is that their ideas don't change: their "truths" are set in the concrete of their unchangeable dogmas. As Oscar Wilde said: "Truth in matters of religion is simply the opinion that has survived."

As binding as that is, religions are hobbled by the principle (which I proposed in the previous chapter) that *if any statement can be demonstrated to be "true", then the demonstration simultaneously shows that the statement doesn't refer to reality*. Consequently, any "proof" of the "truth" of any religious statement (e.g., that God exists, that Jesus was the son of God, that Moses, Muhammad, Joseph Smith, etc. were prophets of God, and so on) simultaneously demonstrates that the statement is just part of some game – and all evidence indicates that it's part of a con-game!

Actually, another principle that suggests that all organized religions are just con games is the following hypothesis (which I haven't seen anyone else propose): *in reality, in open systems, nothing is infinite.*[9] I propose this principle simply by extrapolating from observations. Thus, when one explores any particular case that seems to suggest the existence of some infinity (e.g., the number of sand grains on some seashore, the number of stars, the number of hydrogen atoms in the universe, the size of the universe, etc.), then always what has emerged is not an infinity but a finite number (albeit, in such cases, an astoundingly large number). In contrast, in many closed systems, it's easy to conjure up all sorts of infinities; e.g., in pure math, the number of integers, the number of odd or even integers, the number of prime numbers, and so on. In fact, Cantor developed a methodology to classify different types of infinities that appear in pure math. But all such infinities are for closed systems, and in the open system known as reality, then as far as I can tell, *nothing is infinite*.

As for how the nonexistence of infinities (in reality) suggests that all organized religions are then just con games – or better, that they don't deal with anything real – follows, because as far as I know, all organized

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9 If you noticed that there's a double meaning for my proposed principle, then I admit that I'm proposing both of them! That is, I wouldn't be surprised if, in reality, the "original nothing", from which this universe came into existence, is infinite! But then, since I doubt that humans will ever be able to explore the "total nothingness" that's "outside" our universe, my claim about such a 'nothing' is as "secure" as all claims about God, since no conflicting data will ever be collected, i.e., my statements that this 'nothing' IS infinite (similar to the claim that "God exists") is meaningless.

religions deal with lots of infinities, e.g., with *immortal* gods (i.e., beings that have *infinite* lifetimes) that are omnipotent (i.e., *infinitely* powerful) and omniscient (i.e., *infinitely* knowledgeable), some of whom allegedly dole out *eternal* (i.e., *infinitely* long) bliss or punish with *eternal* (i.e., infinitely long) damnation to *immortal* souls (i.e., *infinite* lifetime). Therefore, in so far as it's correct that, in reality, nothing is infinite, then in reality, gods don't exist (nor do immortal souls or eternal life).

But setting that "demonstration" aside, the restrictions of classic logic to statements with no temporal or spatial dependence requires either 1) that time and space are irrelevant for the system (e.g., in the game of poker, a flush always beats a straight, regardless of where the game is played and what time it is) or 2) if time and space are relevant for the system, then all statements must deal with "stuff" that's invariant in space and time (e.g., momentum and energy in "isolated systems" – topics that I'll get to in the "excursion" **Z_0x**). Otherwise, in reality, change not only occurs, it almost always dominates.

Of course, that change usually dominates was well known to essentially everyone before Aristotle's time (384–322 BCE): even monkeys and babies know things change! One of the oldest books known (~1200 BCE), written ~700 years before the Old Testament was "fixed in time", is the basic book of Taoism, *I Ching,* i.e., *The Book of Changes*. Approximately 150 years before Aristotle, the Ancient Greek philosopher Heraclitus (c.540–480 BEC) wrote: "All is flux, nothing stays still… nothing endures but change." It was, however (and still is!), one thing to know that things change – and another to discern how to describe change.

The difficulty in understanding and describing change is the root cause of the "paradoxes" with which Zeno (a student of perhaps the first to investigate logic, i.e., Parmenides, c.515 – c.450 BCE) tied himself (and many others!) in knots. As I'll show you in some detail in **Yx**, Zeno demonstrated the "paradox" that Achilles would be unable to overtake a tortoise. Similarly, Zeno "proved" that arrows don't move – because at every instant during an arrow's transit toward a target, the arrow clearly stands still (as now can be seen, for example, using still-photography). But as I'll also show you in **Yx**, Zeno's paradoxes can be resolved either by performing the infinite sums (to which they can be reduced) and showing that they have a finite value or by recognizing that his assumptions about simultaneously knowing, with infinite precision, both the speed and location

(of either Achilles or the arrow) are inconsistent with the principle of quantum mechanics called "Heisenberg's Uncertainty Principle".

Even Aristotle's unquestioned brilliance didn't illuminate how to solve the problem of describing change – as his logic reveals. Similarly, nothing changes with time in geometry, in algebra, and in its combination (analytic geometry, developed by Descartes). Approximately two thousand years after Aristotle, Newton (1642–1727), and almost simultaneously Leibniz (1646–1716), developed methods to describe change, at least how to describe change mathematically for physical systems: we describe it as "the methods of calculus", but consistent with Heraclitus' statement "all is flux", Newton called it "the method of fluxions". In its essence, the "method of fluxions" is to take care defining and evaluating limits.

For example, for the case of Zeno's arrow in its flight toward its target, its speed, say s (i.e., the time rate of change of its position) can be found by dividing its change in position, say Δx (as seen, e.g., in two successive photographs), by the time interval between the photographs, say Δt. Thus, the arrow's "instantaneous" speed at any time, $s(t)$, is the limit as $\Delta t \rightarrow 0$ of $\Delta x/\Delta t$, which is written symbolically as the derivative (or "fluxion"): dx/dt. Newton then went on to show how, in turn, speed (or, better, velocity, $\boldsymbol{v}$) of some mass, m, changes, namely, through application of some force, $\boldsymbol{F}$, i.e., $\boldsymbol{F} = m\, d\boldsymbol{v}/dt$.[10] And about 200 years later, Einstein corrected this second "law" (better, "principle") of Newton by showing that, because a body's mass changes with its speed, closer to "the truth" is to say that a body's momentum, $m\boldsymbol{v} = \boldsymbol{p}$ changes according to $\boldsymbol{F} = d\boldsymbol{p}/dt$. Thereby, Dear, you can see that only for an isolated system (subjected to no external forces) is $d\boldsymbol{p}/dt = 0$, i.e., momentum is then a constant.

The method developed by Newton and Leibniz was an enormous advance. In turn, recall Newton's statement in a letter to Robert Hooke (now famous for "Hooke's law" describing the behavior of springs): "If I have seen further [than you and Descartes], it is by standing upon the shoulders of giants." In turn, Descartes acknowledged his reliance on advances made by Galileo. Nonetheless, the methods of taking limits used by Newton and Leibniz needed improvements, and these were accomplished by other "giants", such as Euler (1707–1783), d'Alembert (1717–1783), Lagrange (1736–1813), Cauchy (1789–1857), and Weierstrass (1815–1897).

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[10] I use bold type to indicate that the variable is a vector, i.e., it has both magnitude and direction.

Yet, in a way, all such advances in ability to describe change were really rather pathetic – in that all of calculus deals with change only in mathematical functions, not change in more general ideas. One of the first to see at least one way that ideas change (although apparently he thought that his method described all change) was the "idealist philosopher" Hegel (1770–1831). In turn, Hegel had an enormous influence on Karl Marx (1818–1883), who then thought he saw how all history had changed. The result was communism, which had an enormous influence on the entire world during the twentieth century.

Hegel rejected Aristotle's "either-or" (or black *vs*. white) view of how we think, and instead returned to views closer to those of the pre-Aristotelian philosopher Heraclitus. To see this, first consider what Shakespeare had Hamlet say (consistent with Aristotle's views): "To be or not to be, that is the question." In contrast, Hegel would say something similar to: "To be or not to be is not the important question; the important question is: what shall we become." Specifically, Hegel wrote:

> The truth of Being and of Nothing is accordingly the unity of the two: and this unity is becoming… 'To become' is the true expression for the resultant of 'To be' and 'Not to be'; it is the unity of the two; but not only is it the unity, it is also inherent unrest – the unity… is at war with itself.

Approximately 2300 years earlier, Heraclitus had similar ideas. Only fragments of records of his ideas are available, and most (if not all) of these fragments are records of what other ancient writers (such as Plato and Aristotle) reported were his ideas. The following is illustrative:[11]

> All things happen by strife and necessity… All things come into being by the conflict of opposites… The things that exist are brought into harmony by the clash of opposing currents… The structure of the universe was arranged by one harmony through the blending of opposite principles… There is a backward-stretching tension, as between the bow and the lyre…

It appears, therefore, that Heraclitus thought that all things change through the combination of opposites; Hegel particularly emphasized that our ideas change when we are able to perceive how opposing ideas can be combined into a single idea.

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[11] These fragments from Heraclitus are from a web page maintained by Paul Harrison and entitled "A history of pantheism and scientific pantheism."

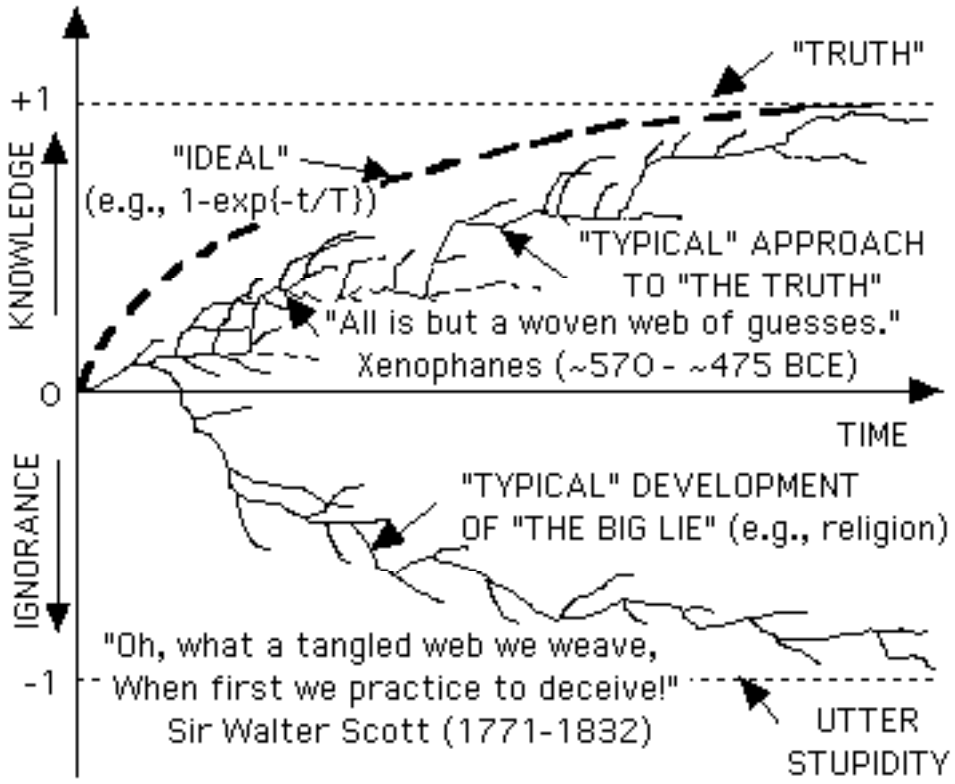
For example, our ideas change (according to Hegel) when we see how to put together the *thesis* "to be" and the anti-thesis (or *antithesis*) "not to be" into the single *synthesis* "to become". The idea that change evolves through the dynamic process of combining a thesis with its antithesis into a synthesis (a process that Hegel called a "dialectic", from the Greek words *dia* meaning 'between' and *legein* meaning, for example, "to choose") is what Marx abstracted from Hegel, leaving behind Hegel's "idealism" and substituting his own "materialism", which is why Marx's philosophy is more appropriately called "dialectic materialism" rather than "communism".

And if the above ideas about change, from Heraclitus to Marx, is far more than you ever wanted to know, Dear, then good – because, what I was really trying to do was build a case to justify my saying the following. Dear, there's no way that, in this chapter, I can describe to you all that has been developed during the past ~300 years to eliminate the inadequacies in Aristotle's logic to accommodate change. Aristotle's ideas (about ideas and logic) were, if not wrong, then certainly extremely constraining: his idea was that ideas are static; in reality, they're dynamic. In science, this dynamism is the scientific method: obtain data, develop a model, test it by obtaining more data, if necessary modify the model, and so on.

More generally, Dear, in all fields of knowledge (from physics to fishing, pharmacy to farming, and philosophy to family planning) we "codify" understanding in a huge variety of models. In each field, when our knowledge and understanding changes, we change the corresponding model – sometimes only marginally but sometimes dramatically, depending on the details of our hypotheses, the change in our knowledge and understanding, and the ability of the "old model" to accommodate changes in ideas.

To illustrate, let me return to the discussion (imagined in the **S**-chapter, among a certain group of grandchildren) about various models of how this world of ours fits within this universe. The first grandchild, GC#1, started with her "flat-plate model", but when GC#2 confronted her with the way ships seem to disappear over the horizon, she changed her model of the Earth from a "flat plate" to a "frisbee". When questioned about why the waters of the oceans didn't roll off her frisbee, she modified her model more (suggesting that there were mountains all around the perimeter) – but I suspect that this *ad hoc* (i.e., "to this" or "for this specific purpose") modification of her model wasn't very convincing, maybe even to her.

Next, GC#2 suggested a "big-ball model" for the Earth, a model that "broke with tradition" (established by GC#1), but probably even GC#1 was willing to abandon her model when she learned that someone had set out on a sailing ship heading west, maintained that course, and returned home from the east! And so on it went, through the models proposed by the other grandchildren. Similarly, for other fields of knowledge, which then leads to a "model of changing models" sketched in the (crummy!) figure, below.



And yes, Dear, I know this is a very "busy figure" – it would be better if I could construct it in on an overhead projector, adding layer upon layer! Failing my ability to do that, I would ask you to go through the figure, step by step, as follows. First, please notice that I've labeled positive and negative regions along the ordinate (or "y-axis") as "knowledge" (or understanding) and "ignorance" (or misunderstanding), respectively, and that I've labeled the abscissa (or "x-axis) as "time". Therefore, what I'm trying to show, overall, is how knowledge and ignorance change with time. Next, notice that I've pretended that "Truth" could be represented by the asymptote $y = +1$. At $y = -1$, I've labeled a "mirror image" to "truth" as "utter stupidity" – although you might want to chose some other name for it.

In the region representing "knowledge" (i.e., y greater than zero, viz., $y > 0$), I've sketched two sets of "curves". One curve (the thick, dotted line) is meant to represent some "IDEAL" smooth, continuous, asymptotic, approach to "truth", for example, as if along the curve $y = [1 - \exp\{-t/T\}]$ (a curve that I've only roughly sketched), in which T is some "time constant" for change (where T would depend on the particular "truth" being investigated, and for some "truths" could be minutes and for other "truths" could be thousands of years). Such a smooth transition toward "truth" is only hypothetical: I doubt that it has ever occurred!

The other, jagged, crazy-looking "curve" in $y > 0$ is meant to represent something closer to reality; i.e., the way that we actually progress toward greater understanding. To illustrate, consider again the grandchildren's models of the world. Starting near time = 0, the first part of the "crazy curve" would represent GC#1's flat-plate model; the first "jag" above the first "leg" of this curve would represent someone's early suggestion that the Earth was more like a ball (similar to a suggestion recently found on an Ancient Egyptian papyrus – but that suggestion apparently didn't receive a wide following until thousands of years later).

Then, continuing along the first part of the curve representing GC#1's model: she modified her flat-plate model to be a frisbee; it's assumed that others suggested other models; she hung on to her model long past when anything but loyalty to a defunct idea would recommend; and eventually there's a major jump upward in knowledge, when GC#2's big-ball model is accepted by essentially everyone – even GC#1 probably abandoned her model when she interviewed the sailors who returned from their trip around the world! And so on, up the "woven web of guesses", toward "truth".

Experience has shown that, in reality, this "model of changing models" is a fairly good representation of both how our ideas change and how progress toward "truth" is made. In general, in open systems, in reality, transitions toward "truth" (and the associated transitions in thoughts) needn't be (and usually aren't) continuous; some progress proceeds by evolution, some by revolution (the run and the jump, "the trot and the leap", or, as with trust, the crawl and the fall!) – and no progress toward truth is possible without courage to overcome the terror of revealing your own errors.

Along the dominant curve in any model development, the "jumps" in understanding are now also called "paradigm shifts", a phrase recently made popular by the science historian Thomas Kuhn (where *paradigm*, pronounced either as "pair-eh-dim" or "pair-eh-dime, is from the Greek words *para*, meaning 'alongside', as in the word 'parallel', and *deigma*, meaning 'example', so a *paradigm shift* is "an alongside-example shift", which in simpler words means "model change").

Three features of paradigm shifts that I hope you'll think about, Dear (and you can learn more about from reading Kuhn's book)[12] are the following:

1. The good fortune for humanity of the "intelligence" [ranging from "dumb luck" (also called "fortuity" or "fortuitousness") to brilliance] of those who are able to conceive new models that become useful for the rest of us (i.e., our indebtedness to such people as those who made stone tools, controlled fire, made pottery, smelted metals, developed a wheel and axle, built irrigation canals, and so on, as well as later brilliant people, such as Anaxagoras, Democritus, Hippocrates, Aristotle, Euclid, Archimedes, the Muslim who invented algebra, the Muslim who started the science of optics, Copernicus, Kepler, Galileo, Newton, Fourier, Darwin, Maxwell, Boltzmann, Planck, Einstein, Heisenberg, Dirac, and more-recent scientists, too numerous to list).

2. The good fortune for humanity of the courage of such people to describe their models to a skeptical, critical, and sometimes very hostile world. In times past, this hostility to new models was primarily from the clerics (witness the cases of Anaxagoras, Galileo, and Darwin), but even today in our country, to propose a new model requires courage to expose yourself to criticism and to error. Of course we all make errors and of course "the only serious error is not to make any", but most people try to hide their errors and are afraid to expose potential errors to criticism.

3. The good fortune for humanity that old people die! The problem is that it's so difficult to get people to change their minds (i.e., relinquish their old models) – as maybe you've already concluded from some of your own data, collected on certain parents and grandparents! In his book,

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[12] Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Third Edition, 1996, The University of Chicago Press).

Kuhn gives two memorable examples. Thus, at the end of his book *Origin of Species,* Charles Darwin wrote:

> Although I am fully convinced of the truth of the views given in this volume… I by no means expect to convince experienced naturalists whose minds are stocked with a multitude of facts all viewed, during a long course of years, from a point of view directly opposite to mine… [B]ut I look with confidence to the future – to young and rising naturalists, who will be able to view both sides of the question with impartiality.

And in his *Scientific Autobiography,* the originator of quantum mechanics, Max Plank wrote something similar:

> [A] new scientific truth does not triumph by convincing its opponents and making them see the light, but rather, because its opponents eventually die, and a new generation grows up that is familiar with it.

So, Dear, good luck to you in your choice of new models – and to demonstrate that at least one old model is wrong, maybe when you, too, become very old, you'll demonstrate that old people needn't become so set in their ways (as some people whom it's perhaps best not to name) that they're unable to recognize the value of some new paradigm!

Meanwhile, on the "ignorance side" of the above figure, there are similar "paradigm shifts", but in this case, the shifts are not usually toward "truth" but toward development of what I've labeled as "the big lie" or "utter stupidity", be it a lie perpetrated by a dictatorship or some stupidity promoted by some religious leader. An example is the development of the monstrous "God Lie" (which I sketched in **Ix** and will show more of in **Yx**), from primitive ideas of spirits and souls, to the lies that some "God" specified laws, and to the "utter stupidities" perpetrated today by all organized religions.

Such stupidities and lies sometimes start from some "honest attempt" to model reality – as I tried to sketch in the above figure by starting the "web of lies" on the side of "truth", i.e., in $y > 0$. Examples include a model for some physical process (e.g., Moses' model for why "Mount Sinai was all smoking", because the LORD had "come down upon it in fire"), a model for societies (e.g., Marx's "the history of all hitherto existing society is the history of class struggles"), or a model for the behavior of people (e.g., Hitler's "the great masses of the people… will more easily fall victims to a big lie than to a small one"). Subsequently, however, when a Moses or a

Stalin or a Hitler uses force to perpetuate his model, then ignorance is well on its way toward "total stupidity". I hope, Dear, that you'll give some thought to differences between people who attempt to understand "the truth" *via* the scientific method *versus* those who develop and promote such lies in some closed-system "ideology" – and the harm that the latter can do to humanity.

Thus, Dear, consider the harm done to humanity by the fools who promote models that can't be tested and/or ignore (or even suppress) data that suggest that their models are in error, the harm done to humanity by the cowards unwilling to reveal their potential errors, the harm done to humanity by the liars and thieves who purposefully perpetrate their deceptions for their own benefits, and the harm done to humanity by the brutes who use force to impose their models on others. In later chapters, I'll show you some of the harm they've done. Also in later chapters, I'll at least attempt to explain the rest of the topics that I review with "T" and that I feel I covered inadequately in these two chapter dealing with "Truth". Here, I'll just list some of the topics that I feel I covered inadequately and indicate where, in later chapters, I'll try to remove these inadequacies.

- In **U**, I'll try to show you more about the critical importance of trial and error and associated criticisms. Let me summarize this way: all of knowledge is a web of wild and wooly guesses, *woven through trial and error.*

- In **V**, when addressing concepts of values, I'll not only address "the science of values" but also I'll return to the inadequacies in the basic assumption of all religions that the universe is a closed system.

- In **W**, dealing with "Words, Wisdom, and Worldviews", I hope that you'll more clearly see what I mean by *religious truth isn't real, and scientific truth can't be realized,* and also, that mathematical truth is possible – but only as part of a game.

- In the many **X**-chapters, I'll try to show you some of the many changes in ideas that are now occurring in the world – and the many changes still needed if ever humans are to edge closer to "peace and plenty".

- In the **Y**-chapters, which focus on **Y**ou, I'll return to the challenge of change; in particular, the challenge that you'll need to face to accept change, overcoming feelings that can range from timidity to terror. Here, I'll just summarize with the recommendations: whereas change is inevitable, work with it, welcome it, go with the flow. In contrast, religious people fear change; therefore, they cling to the only thing that's changeless: fictitious stories and word games.

- In the "excursion" **Yx** (dealing with "Your Indoctrination in the Mountainous God Lie"), I'll try to justify my summary: all religions are webs of sticky, closed-system "truths" in which all clergy, like black-widow and brown-recluse spiders, feed on those they snare in their web of lies and stupidities.

- In **Z** (dealing with the Zen of Zero) and its "excursion" (**Z_0x**), I'll review some of the scientific principles and theories that have been discovered – but I'll generally restrict my coverage to those principles that I'll want to use to try to show you how the universe might have created itself from "total nothing" (i.e., the "original zero").

As for now, toward closing this chapter, let me first remind you of a famous statement by Newton.

> I do not know what I may appear to the world; but to myself, I seem to have been only like a boy playing on the seashore, and diverting myself in, now and then, finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.

What I hope you see, Dear, it that, almost certainly, all we'll ever be able to do is find a few more "smoother pebbles" or "prettier shells". That is, so long as we're restricted to approaching the truth only asymptotically, then "the great of ocean truth" will almost certainly forever remain unexplored.

I hope, Dear, that you've found these ideas about "truth" both trivially obvious and obviously nontrivial. From such ideas, it's necessary to make a choice: either one chooses to pursue the concept of "truth", thereby restricting one's interest to closed systems (such as pure mathematics, games, and religions) or one chooses to abandon the search for "ultimate truth" and deal with reality (i.e., open systems), in which the best one can do is obtain estimates for the probability that any statement is "true". As Popper said: "…in our search for truth, we have replaced scientific certainty by scientific progress."

Again, Dear, truth and reality are irreconcilable: *nothing real can be demonstrated to be "true", and as far as we know, nothing "true" is real!* Further, *for real systems (that is, for open systems), the best "guides for living" are hypotheses that succintly summarize a substantial quantity of reliable data, whose predictions have been validated, which in principle can be falsified, but which have not yet been falsified; i.e., the best we can do in this real "game of life" is just "muddle by" with "useful working hypotheses."* Thereby, Dear, if ever you set yourself the goal of proving that something is "true" (e.g., that God exists), then simultaneously you will be

setting yourself the goal of demonstrating that it has nothing to do with reality: the most you'll end up doing is playing word games, such as "God is love" or "beauty is truth, truth beauty". Such results may sound good, they may invoke emotions, but they demonstrate nothing except the emotional appeal of (and possibly a predisposition of our minds to absorb) lilting phrases and fanciful images. Welcome to the world of muddling by!

Similarly, Dear, if ever the idea of God can be shown to be true, then that's exactly when, once and for all, the God idea can be totally discarded, since simultaneously, it would demonstrate that all "God stuff" is just a game. What is needed, instead, is some way to test if the idea of God is false: if ever such a method is conceived, then I would withdraw by description that "God's a bunch of garbage." Until then, it's precisely because no methods have yet been identified to test either that God exists or doesn't exist (and exactly the same for Superman or any other story-book character) that "belief" in such characters is nothing but a game. The value of this game to the con-artist clerics is undeniable, but there's less than zero value of this game to the con-artists' marks, i.e., to the huge number of people who have bought into the con game.

Meanwhile, in reality and in many cases, it's relatively easy to identify the best hypothesis among contenders: for example, after testing various hypotheses for quelling a headache, you needn't use mathematical manipulations of Bayes' method. Instead, using common sense and following your natural predilection to apply the scientific method in your daily life, you might find that what usually does the trick is to lie down for a while with a wet cloth containing some ice cubes! In more complicated cases, however, to extract understanding from knowledge, in turn from information, is a much bigger "headache" than gaining knowledge about how to quell a headache.

In fact, there are many headaches not just from uncertainties about relevant hypotheses (which ones seem most likely to be valid, how to test them, how many to test, etc.) but also in some cases, about a huge number of uncertainties and associated questions, such as: What are the causes of the results being investigated? Are there fundamental uncertainties in the processes under investigation? How accurate are the proposed measurement programs? Etc. Those are topics that I want to address in the next chapter, entitled "Understanding Ubiquitous Uncertainties" and which, with a little bit of luck, will be waiting for you after you get some exercise!