THE SCIENTIFIC METHOD by Michael Disney

Draft 05/08/21 (4.8 k-words)

INTRODUCTION

The witty zoologist Peter Medawar wrote "*Ask a scientist what he considers the scientific method to be, and he will adopt an expression that is at once solemn and shifty eyed: solemn because he feels he ought to declare an opinion ; shifty eyed because he is wondering how to conceal that he has no opinion to declare"*. Alas he then went on to claim that the philosopher Karl Popper (Falsification) had worked out the secret. But he hadn't : Falsification is no more reliable than 'Corroboration'. However the real high priests of Scientific Inference were mathematical types like R.A. Fisher and Harold Jefferies. But they were wrong too because Probability Theory only works in CLOSED systems, all of whose possible configurations can be enumerated and evaluated (e.g. games), whereas the real world is OPEN. Thus the secret of Science, its Method if you like, must lie elsewhere .

Those of us who actually do science for a living know that it is a messy business of trying, failing and trying again, unlikely to be explicable in terms of either philosophy or mathematics. Einstein averred that: *"Science is no more than a refinement of everyday thinking."* but admitted: *"The physicist cannot proceed without considering critically a much more difficult problem (than physics), the problem of analysing the nature of everyday thinking.*"

Perhaps we can excuse our predecessors for imagining that some kind of mystique was involved because the almost overnight transformation of hunter-gatherers into space-travellers did seem to call for divine intervention. After all, as we *now* know, we share 98% of our genes with chimpanzees – who still struggle to crack nuts in the jungle, while Evolution is painfully slow. So

something must have happened about 3000 years ago which increased a millionfold humankind's capacity to think, plan and achieve. (See Sect.5)

Twenty years ago, when my own scientific project (Hidden Galaxies) got wrecked on the reef of conflicting evidence I set out in search of the Scientific Method (SM) hoping it would rescue the day. Gradually I realized that nobody qualified to know had actually captured the process in words, mainly because they hadn't asked the question 'How do animals think?'. Surely, if we can do so, we must have inherited that ability, like all the rest of our survival machinery, from them. Wild animals have to be damned good at making decisions – otherwise they wouldn't survive. Any doubts about that, so long fostered by priests, have been thoroughly dispelled by modern ethologists like Jane Goodall and Frans de Waal.

Sticking doggedly to that much simpler question, and ignoring the seductions of mathematics (after all ravens, who are very smart indeed, don't appear to use it) the outlines of common sense thinking (CST) began to emerge from beneath a heavy over-burden of confusing scholarship. The main mechanism is the simple association of ideas; the main objective is hypothesis testing (against evidence); and the basic tool is 'Categorical Inference' i.e. pigeon-holing clues (for or against) into only three categories – strong, weak or neutral. Gambling is clearly involved because at some stage a decision to act must be taken, even when the odds on its wisdom can hardly be certain. More than anything else a futile search for Certainty has blinded scholars, holding up progress for millennia. Scientists succeeded, where others failed, because they turned their backs on Certainty and contented themselves with accumulating evidence until the odds, for or against, this or that hypothesis, looked persuasive. In the next section, through examples, we demonstrate CST at work. Afterwards we'll show how, with the aid of a pen, CST got us to the Moon – and far beyond. And, as one might expect, there are many implications of CST – correctly understood – which go well beyond Science.

2 CATEGORICAL INFERENCE (CI)

Smart animals appear to alter their outlook on some hypothesis ('master's taking me fora walk') according to the rule:

(A) New outlook = category of clue • old outlook

where there are only 3 categories of clue: strong(s), weak(w) and neutral(n) while clues against are underlined (s ,w) and • is a symbol for 'combined with'. Thus a detective considering the guilt of some suspect X (her hypothesis) might think along the following lines;

INFERENCE TABLE 1: DETECTIVE-THINKING

HYPOTHESIS: "X is guilty"

	2	3	4
Clue	Category	New outlook	Action
Prior (outlook)		n (dispassionate)	
Motive	s	s • n = s	
Opportunity	w	w • s = ws	
Alibi	w	w• ws = s	
Witness A	w	w • s = ws	
Witness B	s	s • ws = w	
Witness C	w	w • w = s	
Witness D	s	s • s = ss	
Witness E	s	s •ss = sss	Charges X

The obvious rules for combining categories are in column 3 while the last row shows her decision to act. Why on sss and not on ss or ssss…? Not ss because of only two strong clues one could be wrong: we often misjudge matters, which for an animal in the wild could mean death. And not ssss or higher because that super-caution could entail too many lost opportunities, even

starvation out in the bush. So action only on sss is presumably the outcome of aeons of Evolution.

The above process of Inference can of course be only suggestive, but it has great merits from the point of rooting humankind's capacity to think in animal behaviour, because there is nothing in the table which a cat or a sparrow couldn't manage.

For those already familiar with Arithmetic it may be easier to translate the categorical symbols into familiar numbers thus: s = 4; w = 2; n = 1; $\underline{s}$ =1/4; $\underline{w}$ = ½ while • becomes the multiplication sign × and where the 'Outlook' becomes 'The combined Odds on hypothesis H given the evidence E, or O(H|E)'. Thus Table 1 becomes Table 2:

INFERENCE TABLE 2

DETECTIVE-THINKING USING NUMERICAL SYMBOLS INSTEAD

HYPOTHESIS: "X is guilty"

Clue	Weight	Odds on H given E O(H|E)	Action
Prior		1	
Motive	4	4×1 = 4	
Opportunity	2	2×4 = 8	
Alibi	1/2	½ × 8 = 4	
Witness A	2	2×4 = 8	
Witness B	¼	¼× 8 = 2	
Witness C	2	2 × 2 = 4	
Witness D	4	4×4 = 16	
Witness E	4	4×16 = 64 to 1 on guilt	Charges X
Forensics(later)	1/128	(1/128) ×64 = 1/2	Dismisses X's guilt

There is *nothing* more refined about this table than the first; it is *not* Mathematics; we have simply taken advantage of our familiarity with arithmetic symbols to make it easier for humans to interpret. Now add two real refinements:

One doesn't have to start the process of inference from a neutral Prior (n or 1). For instance if there were only 5 possible suspects the detective might have started her train of inference against X with a dispassionate Prior of 4 to 1 against his guilt or ¼ while a scientist considering a dramatically unlikely hypothesis might be wise to start from an even more sceptical Prior of say 1/32 or 32 to 1 against (later).

To the modern scientist who can make precise measurements all this may seem primitive, even though it is the outcome of a billion years of Evolution. Thus a forensic scientist might claim for his results on X's guilt a far higher Weight (category) than ¼, say ssss or 1/128 (added row, second table) leading to the opposite conclusion – Innocence.

Here we come to an absolutely vital distinction – between precision and Weight. No matter how precise a measurement is the Weight it can bear on some hypothesis W(E|H) should nevertheless be limited. The history of Science is littered with so called 'Systematic Errors' – the 'unknown unknowns' which can make a nonsense of precise measurement or calculation. The fact that seismic waves can propagate through the globe was used to argue that the Earth must be rigid, thus denying Continental Drift for 50 years. The Systematic Error here was the unconscious assumption that because rock is rigid on a timescale of seconds (waves) it must also be so on timescales of hundreds of millions of years, which it is not (see the spectacular folding of geological strata).

Along with a misbegotten search for Certainty, over-weighting plausible systematic errors has been one of the two great drags on human progress;

examples include : the Earth is flat; is the centre of the Universe; is far too young for Evolution to be significant; planetary orbits must be circular; childbed fever is an unavoidable part of birthing; wireless waves could never girdle the globe; Time is absolute…… . The way to prevent Systematic Errors from leading us astray is what I call the "Principle of Animal Wisdom", or the PAW:

> **THE PRINCIPLE OF ANIMAL WISDOM (PAW) :**
> THE WEIGHTS OF ALL CLUES AND ARGUMENTS SHOULD BE CONFINED TO ONE OF ONLY THE FIVE VALUES: (4,2,1, ½, or 1/4).

In other words I claim that Nature's simple choice in Categorical Inference (CI) cannot be improved upon, that it should make just as much sense to the modern scientist as it does to the wildebeest. In both cases it helps to avoid fatal mistakes and reminds us that the real world is OPEN to hypotheses we may not have even considered. For instance the interpretation (weighting) of forensic DNA evidence, despite its enormous precision, is often problematical [e.g. neglecting to put in a proper Prior on Innocence leads to the 'Prosecutor's Fallacy'].

Statisticians (Probabalists in general) may reject the PAW because it renders their profession largely redundant, certainly so far as hypothesis testing is concerned. What possible point can their 4-figure accurate tables have when the combined Weights (which are all that matter) can have a precision no better than the *least* precise Weight included – probably precise only to within a factor of 2 ? They have misled themselves, and everybody else, by forgetting the distinction between OPEN (real) and CLOSED (model) worlds. While the latter are susceptible to very precise predictions, they themselves are often rickety models of reality. Celestial mechanics could precisely predict the return of Halley's comet only because it assumed the orbit would not be deflected by a

passing star. And because stars are so far apart (as we know *now*, but not then) that worked out – fortuitously.

On the face of it the PAW is so crude that it might seem to undermine the case for modern precise science. But it does not because of an invention made by the Phoenicians about 3000 years ago somewhere near Byblos – *phonetic* writing. Animals' and illiterate humans' ability to make use of Categorical Inference (CI) is limited by their capacity to reliably store, weight and combine more than so many clues [perhaps 3 or 4]. But with writing, that capacity became, at a single leap, unlimited. To illustrate how writing could revolutionize thinking let's look at it working in the scientific controversy over 'Hidden Galaxies'. I choose that field only because, having started it, I am aware of all the tortuous snakes and ladders involved, something it would be impossible for me to follow in any other. Moreover it is real, not some simple didactic model. In Table 3 the left side represents my thinking without PAW (Weights W(E|H) between 2^{-6} and 2^{4}) the right side with PAW (Weights between 2^{-2} and 2^{2} only). The actual clues don't matter because it is only the *process* which interests us here, not the topic itself.

INFERENCE TABLE 3

HYPOTHESIS: "The Cosmos contains significant numbers of Hidden Galaxies"

1	2	3	4	*	5 (PAW)	6 (PAW)
Clue #	Date	W(E|H)	O(H|E)	*	W(E|H)	O(H|E)
Prior			2^{-5}	*		
1	1975	2^{4}	2^{-1}	*	2^{2}	2^{-3}
2	1978	2^{-3}	2^{-4}	*	2^{-2}	2^{-5}
3	1983	2^{2}	2^{-2}	*	2^{2}	2^{-3}
4	1984	2^{2}	$2^{0} = 1$	*	2^{2}	2^{-1}
5	1985	2^{2}	2^{2}	*	2^{2}	2

6	1987	2^1	2^3	*	2	2^2
7	1987	2^3	2^6	*	2^2	2^4
8	1990	2^2	2^8	*	2^2	2^6
9	1993	2^2	2^{10}	*	2^2	2^8
10	1994	2^3	2^{13}	*	2^2	2^{10}
11	1995	2	2^{14}	*	2	2^{11}
12*	1995	2^{-5}	2^9	*	2^{-2}	2^9
13	1997	2	2^{10}	*	2	2^{10}
14*	1997	2^{-5}	2^5	*	2^{-2}	2^8
15	1998	2^2	2^7	*	2^2	2^{10}
16	1999	2^{-1}	2^6	*	2^{-1}	2^9
17	2002	2^{-1}	2^5	*	2^{-1}	2^8
18	2002	2^{-1}	2^4	*	2^{-1}	2^7
19*	2005	2^{-6}	2^{-2}	*	2^{-2}	2^5
20	2005	2^2	1	*	2^2	2^7
21	2007	2^2	2^2	*	2^2	2^9
22	2009	2	2^3	*	2	2^{10}
23	2012	2^4	2^7	*	2^2	2^{12}
24***	2013	2^{5+5+6}	2^{23}	*	2^{2+2+2}	2^{18}
25	2013	2^2	2^{25}	*	2^2	2^{20}

Note: Clue 24 simply compensates for the 3 erroneous (asterisked) clues.

The first thing to notice is how many clues may be needed to settle a sophisticated argument – far beyond the capabilities of any illiterate. Thus writing could well be the transformative development we were looking for, and its evolution did coincide, both in time and space with a spectacular take-off in human progress. The Greeks in particular improved the Phoenicians' invention,(by inventing vowels) and exploited it.

The second, much less obvious, factor is that the PAW actually improves the quality of the thinking. With PAW we could have arrived at a decisive (and sound) conclusion in the early 1990s whereas without it we were still arguing 20 years later (some still are). Why? Because PAW disarms systematic errors by refusing to give a Weight of more than 4 (or less than ¼) to *any* clue. Thus the 3 strongest arguments (asterisked) against the hypothesis all turned out to be systematic errors – based on the same natural but misbegotten assumption. Had I known about the PAW at the time I would have looked askance at the three strong adverse clues, which looked anomalous, and perhaps identified their underlying fallacy.

I conclude that far from undermining the power of Scientific Inference the crudity of PAW can greatly enhance it.

3 CHOOSING HYPOTHESES

Usually there is only a limited amount of good evidence about so it is vital to choose hypotheses which are easy to either corroborate or dismiss, especially so in survival situations where speed may be existential. This turns out to be a subtle matter. Newton, Darwin and Einstein leaned heavily on a principle called 'Ockhams's Razor (OR)' – without understanding how it worked. Let's' employ CST on another astronomical example, to see if we can make sense of it.

Back around 1910 astronomer X was struggling to take the first photographic spectra of the mysterious 'white nebulae' ['galaxies'] and obtained the results shown in Fig 1. He was astounded to discover their colossal redshifts – which appeared to increase systematically with distance. The crazy idea that the whole universe might be expanding crossed his mind – but what were the Odds on it – given his data? Would publication earn him lasting fame – or ridicule? A steadily expanding universe ought to yield a straight line

sloping up towards the right (I in Fig 1) while the Odds would depend on the discrepancies of his data-points (in terms of their error-bars) from that hypothetical line:

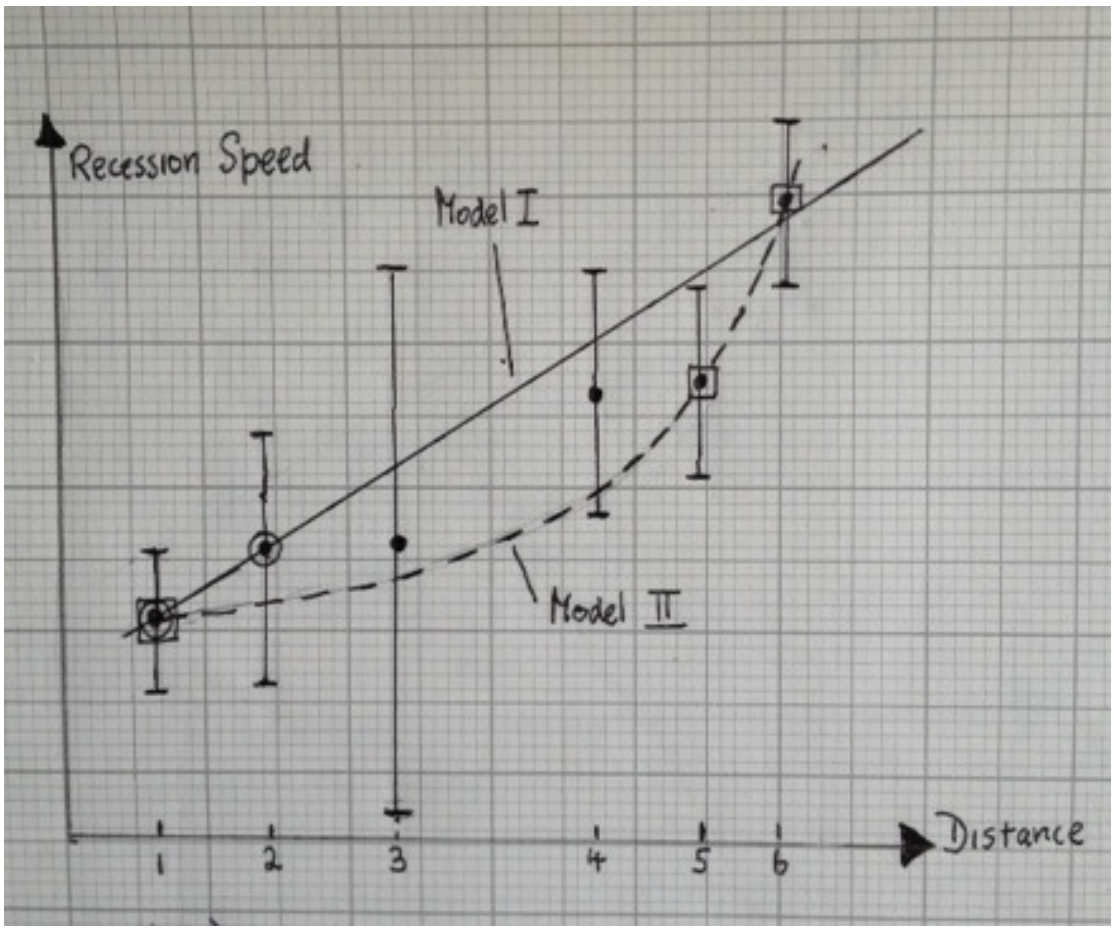

Fig 1: Astronomer X's redshifts or recession speeds (with error bars) for 6 white nebulae labelled 1 to 6, plotted against rough estimates of their relative distances. No scales are shown or were needed to test his hypothesis of expansion. The Model I line is for steady expansion, the Model II curve is for slowing expansion due to gravity; it's steeper in the past, i.e. in the distance.

First though he had to estimate the slope of that line – which he did by fitting it exactly through his two best points (1&2). Then he went to the library to obtain Weights for his 4 remaining points , which he found in a tome on "The Theory of Errors". They enabled him to compose the following Inference Table (IT):

INFERENCE TABLE 4

HYPOTHESIS: “Universe is expanding steadily”

Clue	Discrepancy	Weight	O(H|E)
Prior			1/2[a]
Point 3	0.2	5[b]	5×1/2 = 5/2
Point 4	0.4	2	2×5/2 = 5
Point 5	1.0	1/2	½ ×5 = 5/2
Point 6	0.1	12[b]	12× 5/2 = 30 to 1 on

Superscript b: didn’t use PAW.

X was thrilled by his combined Odds of 30 to 1 on H – which matched his intuition. Perhaps his crazy idea wasn’t so crazy after all.

Over the following weeks he agonized over whether to publish or not. While the Odds looked good they were by no means clinching. Then it occurred to him that gravity between its receding parts ought to cause a slowing expansion, to a curve more like II, steeper in the past (in the distance because of the finite speed of light) than it was today (nearby). Excited he built a new IT (4A below) based on curve II which he now fitted exactly through the three points 1, 5 &6 . The Prior he dropped to 3:1 against, because now there were 4 possibilities: static; collapsing; expanding steadily, slowing expansion.

INFERENCE TABLE 4A

HYPOTHESIS: "Universe expanding but decelerating"

Clue	Discrepancy	Weight	O(H|E)
Prior			1/3
Point 2	0.4	2	2 × 1/3 = 2/3
Point 3	0.1	12[b]	12 × 2/3 = 8
Point 4	0.8	1	1 × 8 = 8 to 1 on

Superscript b: PAW not used.

How disappointing, and yes how surprising too. Despite a model with more Physics (gravity) and fitted perfectly through 3 instead of 2 points the Odds have *dropped* .

What's going on? He's run into 'Ockham's Razor' (OR). By complexifying his hypothesis he's actually reduced the Odds on it. Why so? For 3 *separate* reasons: the Prior Odds against it have increased (because there are more possibilities); one more (good) data point has been swallowed up in actually specifying the new hypothesis, leaving only 3 (instead of 4) to calculate the Odds in its favour; and finally the points that are left are probably those of the lowest quality (least Weight). And you can see which way the trend is going. Eventually, by complexifying further, he could fit a curve perfectly through every one of the data points, leaving none left over to calculate the Odds on it. It would then be a Just-So story, not a useful scientific hypothesis. It illustrates how frugal one must be in introducing a new Free Parameter into any hypothesis-test. Do not do so unless it improves the *overall* Odds on that hypothesis, taking into account the generally deleterious affects of complexification.

OCKHAM'S RAZOR (OR 'PARSIMONY')
Always prefer simpler hypotheses to complex ones because, if they fit the data, they are more likely to be right and because in general they are easier to falsify or corroborate. Ignoring OR, or resurrecting failing hypotheses with more free parameters, can

The above example is roughly based on the story of the American astronomer Vesto Slipher who first obtained such data at Flagtaff, Arizona between 1910 & 23. He never made a claim for cosmic expansion so never got the glory – which oddly went to Edwin Hubble – who never believed in it either, although he lived until 1956.

I conclude this section by considering the current status of the Big Bang hypothesis [Table 5]. Professional cosmologists may well disagree with my Weights (PAW) but the table is at least a transparent and civilized tool for carrying out such a discussion.

INFERENCE TABLE 5

HYPOTHESIS: "The Big Bang Theory is basically sound."

# Clue	Weight	O(H|E)	Note
Prior		2^{-5}	F
1 Nothing older than expansion age	2^{2}	2^{-3}	
2 Earlier hot dense state	2^{2}	2^{-1}	
3 Universe should, but does not decelerate	2^{-1}	2^{-2}	
4 U. should be but is not anisotropic	2^{-2}	2^{-4}	
5 Galaxies don't dim with redshift, but should	2^{-2}	2^{-6}	G
6 Big Bang could produce Light elements	2^{2}	2^{-4}	
7 Big Bang predicts structure peaks	2^{2}	2^{-2}	
8 Big Bang cannot produce galaxies	2^{-2}	2^{-4}	
9 But CDM variant can	2^{1}	2^{-3}	
10 But galaxies don't resemble CDM ones	2^{-1}	2^{-4}	
11 'Inflation' may explain isotropy.	2^{1}	2^{-3}	H
12 Recent accelerating expansion unexplained	2^{-2}	2^{-5}	I
13 No sign of Dark Matter in 50 years looking	2^{-1}	2^{-6}	
14 Hubble parameter 'tension'	2^{-1}	2^{-7}	128:1 ag.

Table 5 Notes: (F) a moderately cautious Prior; (G) Tolman's classical test for expansion, failed by factor of 10,000! ; (H) ad hoc, no backing evidence ; (I) Another miracle required here: (Dark Energy?)

Since this is not an article on Cosmology I won't make much of Table 5 though, as an extragalactic astronomer, I believe it is a not unreasonable accounting of Big Bang Cosmology today. The fact is that whenever that hypothesis has clashed with new data its enthusiasts have rushed to rescue it by introducing new Free Parameters, without admitting that by complexifying they have weakened it significantly, perhaps mortally. For instance it was a great shock to find that the Cosmic Background radiation was almost perfectly isotropic [Clue 4] – when it shouldn't be because new regions, never previously in causal contact, appear over the horizon every day. So the extremely vague idea of 'Inflation' was introduced to square the circle. Likewise Dark Matter, CDM and latterly Dark Energy as an outrageously ad hoc explanation for 13. To me Big Bang Cosmology is now wholly unpersuasive because it has 17 Free Parameters, 4 more than the number of *independent* measurements bearing on it. Some of it may be right but…….

How could 'professionals' disagree? By remaining oblivious to the PAW they can then put arbitrarily high Weights on their preferred clues and so cling to their beliefs indefinitely. But 'What if those clues are systematic errors?' The historian Daniel Boorstin remarked: *"The greatest obstacle to discovery is not ignorance – it is the illusion of knowledge."* Perhaps there's something far more interesting than the Big Bang out there?

Ockham's Razor was largely responsible for the acceptance of Heliocentricity, Universal Gravitation, Evolution, Relativity….so we all need to understand and use it in Science, as most of us animals do in daily life (when you lose your specs, you appeal to OR to find them) .

4 A LITTLE HISTORY

The history of Thinking, and hence the of the SM, is tangled. There have always been Empiricists who were content with common sense odds, and Rationalists, descendants of priests and Greek mathematicians, who demanded Certainty. We moderns have been caught between the two, especially when we were taught Statistics, which is neither one nor the other; the enormous rows which rage within that profession are testament to its divided brain.

The fundamental rule of CI:

(A) New Outlook = Category of Clue • Old outlook

was eventually (1921) glimpsed by Rationalists as "Bayes' Rule in Odds form":

(B) $O(H|E_2) = W(E_2|H) \times O(H|E_1)$ which *could* have been cycled up to any number of independent clues as:

(C) $O(H|E_1,E_2,\ldots E_n) = W(E_1|H) \times W(E_2|H) \times \ldots\ldots\ldots \times W(E_n|H) \times O(H)$

which I call The 'DETECTIVE'S EQUATION' (DE). It is the $E=mc^2$ of CST and is the symbolic underpinning to all the Inference Tables used here. But by massive ill luck the Rationalists never reached the DE because they didn't use Odds but the Probability notation P(H|E) instead, in which the DE is such an algebraic nightmare that is was never spotted and therefore never used for 300 years – an epic tragedy for civilization. Notation can really matter.

Odds and Probabilities are simply related, so it is easy to show:

(D) $W(E|H) = P(E|H) / P(E|H^*)$

Where H* stands for "*All those hypotheses H_i , which together might account for H, bar H itself".* ..

Expression (D) above is dynamite because it reveals that certainty [i.e. some W(E|H) becoming infinite] was/is completely unattainable in the *real* world because how could anyone prove that *all* the constituent $P(E|H_i)$' s within $P(E|H^*)$ are zero? This is good news for us simple-minded Empiricists but devastating for Rationalists – Probabalists and Statisticians in particular. Their sought-for high

and precise Weights (e.g. their 4-figure tables) are not only forbidden by the PAW but, in the real (OPEN) world , wholly unattainable.

What rescued the day was the invention of phonetic writing, which overcame the limits of animal memory, so allowing any number N of clues to be compounded by CI [Table 6] to reach such persuasively high Odds, even where the evidence conflicts (thus a lower *average* Weight $\langle W \rangle$), that the need for Certainty became redundant. Given sufficient ambition, curiosity (breadth) and doggedness, tasks far beyond the grasp of illiterate beings could now be accomplished.

TABLE 6

HOW LITERACY BOOSTS DECISIVENESS

(1)	(2)	(3)[a]	(4)[b]	(5)
Thinker	N	$\langle W \rangle$	$\langle W \rangle^N$	Odds[c]
Our Cat	3	4	2^6	64:1 on; Decisive w. strong clues only
Me	3	4	2^6	ditto
Me and Pen	10	4	2^{20}	Millions to 1 on; Very decisive
Me and Pen	10	1.5	60	Decisive with conflicting evidence.
Team and Pens	15	1.5	400	Decisive with conflicting evidence
Research Community	25	1.2	100	Decisive with very confused evidence

Notes: (a) $\langle W \rangle$ is the geometric mean Weight of all the N clues used. With PAW its maximum value can be 4, but as conflicting clues are included so the mean value will fall, until it may barely exceed 1. Yet with enough clues N a decision can still be reached. (b) The combined Weight of the N clues compounded together. (c) Odds of 64:1 correspond to 3 strong clues, which are decisive in CI. Dismissal of the hypothesis would come with Odds of 64 or more to 1 *against*; in that case Col. (3) would needs be less than 1. Einstein summed it up: "My pencil and I are much smarter than I am."

So the scientific method looks to be a mix of plumbing, literacy and common sense (Categorical Inference). It is hardly surprising that academic 'philosophers of science' have got hold of the wrong end of the stick, or that practicing scientists have mostly ignored them.

5 SOME WIDER IMPLICATIONS

In our search for the scientific method we have stumbled upon the simple secrets of common sense itself – of far wider significance. If indeed Categorical Inference is the way all of us animals think then we can draw some useful conclusions. For instance:

- Almost all serious arguments in the real world can reach only provisional conclusions, leaving room for new evidence to turn up. Thus *Provisionality*, and with it *Tolerance*, must become the by-words of Civilization .
- Given that the Association of Ideas is the basis of CI, everything new we learn is valuable in proportion to *what we already know*. Curiosity, breadth and life-long learning are thus the keys to wisdom.
- Hypothesis-testing can best be done using the Detective's Equation. We can largely dispense with statistics with all its internal wrangles, its inconsistencies, its dependence on unrealistic models and its avoidance of the systematic errors which often make a nonsense of its predictions.
- CI will only work where there are a limited number of hypotheses to choose between. This may entail assuming certain 'Principles of Uniformity' (David Hume) such as "All Oxygen atoms are much the same everywhere", which may work better in some fields (the natural sciences) than in others such as Economics and Psychology. Indeed, I cannot see how the two latter could ever become Sciences.

IN CONCLUSION

In the nature of things no one can prove that Categorical Inference is the way that the mind, and with it the scientific method, actually works. However we can say – because of the repetitive nature of the Detective's Equation – that it could have naturally evolved from extremely primitive (one-clue) beginnings while we have demonstrated that, combined with

writing, it can settle exceedingly complex arguments. And the coincidence in both time and space between the invention of phonetic writing and the take-off in human capability, is pretty suggestive.

The futile search for a certainty which is not available, has held up progress for millennia. Liberated from that, and confident of literate common sense instead, there is no knowing how fast we humans could now progress.

BIBLIOGRAPHY

1. This article is a digest of *"Thinking For Ourselves"* by Michael Disney, Amazon Books, 2020; see description at my website mjdisney.org , or at https://mjdisney.org/wp-content/uploads/2020/10/tfotoc.pdf .

2. The references to quotes in the text can all be found in the above book or in *"Scientific Method in Practice"* by Hugh G. Gauch Jr., CUP, 2003, which I find the best and most readable book on the *conventional* view of the Scientific Method (very different from ours).

3. Anyone who doubts that some animals can be very smart indeed should read: *"Are We Smart Enough to know How Smart Animals Are?"* by Frans de Waal, Granta Books, 2016.

4. A balanced and readable account of modern Cosmology is *"In Search of the True Universe"* by Martin Harwit, CUP, 2013

5. An up to date, popular account of Hidden Galaxies is "*Taking a Dim View"* by Adam Hadhazy, *Astronomy*, Oct 2018, pp 44 -51.

6 You can watch a 45 min interview with the author talking about Cosmology on YouTube at:

https://www.youtube.com/watch?v=KskJrJmfr34