Unlaws: the missing “dark matter” in the philosophy of science?

ABSTRACT

Science is sometimes defined as the systematic study of the physical world with the aim of discovering laws of nature. Laws embody generalizations connecting different phenomena, often involving a causal link between one concept and another. I suggest that much of science in fact depends on the opposite idea: the “unlaw”, defined as the proposition that two variables have *no* causal or mathematical link with one another. This idea unifies such apparently distinct notions as thought experiments, conservation principles in physics and experimental design paradigms in the life sciences, as well as highlighting the importance of diversity in the human condition. I propose that the importance of unlaws be acknowledged, and that this category be given due consideration in the philosophy of science, where it may help to resolve some persistent misunderstandings.

> "They gave it me," Humpty Dumpty continued thoughtfully, as he crossed one knee over the other and clasped his hands round it, "they gave it me – for an un-birthday present."
>
> "I beg your pardon?" Alice said with a puzzled air.
>
> "I'm not offended," said Humpty Dumpty.
>
> "I mean, what *is* an un-birthday present?"
>
> "A present given when it isn't your birthday, of course."
>
> Alice considered a little. "I like birthday presents best," she said at last.
>
> "You don't know what you're talking about!" cried Humpty Dumpty.
>
> *Alice through the Looking Glass*

INTRODUCTION

Dark matter accounts for a large part of the mass of the universe, but its existence was not even suspected until Swiss astronomer Fritz Zwicky came up with the concept in the 1930s. The theme of this chapter is that science likewise relies on a group of ideas whose importance, as a category, we have until now failed to appreciate. This failure distorts the picture that science presents to the wider world, and leads to hostility, especially among our colleagues within the humanities, towards what they see as science’s blindness to the diversity of human experience. It also leads to criticism from philosophers, who perceive the conceptual gap and dare to ask the difficult questions, but fail to elicit an answer from conventional scientific accounts. This paper is an attempt to address these confusions, and to suggest that thinking about science from a new perspective can reveal fundamental, and surprising, connections which integrate theory and practice across a broad range of scientific disciplines.

One definition of a scientific law is that it states a link, of a mathematical or causal nature, between two or more variables. In the spirit of Humpty Dumpty, I define an ‘unlaw’ to be a statement of a *lack* of association or causal linkage between two or more variables. In its simplest form, this may state that two variables are statistically independent, that is, that knowledge of the value of one variable gives us no additional information enabling us to predict the value of the second variable[1]. One example might be, that whether today's date is odd or even has no predictive value regarding the likely mean temperature in London tomorrow.

The idea of unlaws was suggested by the Daoist tradition of philosophy, in which the world is seen as made up of a mixture of positive (yang) and negative (yin) elements. In our present context the laws of nature are yang, but the unlaws supply the essential yin element. A familiar example of this essential duality is music, where the intervals between the notes are as essential as the notes themselves.

I will argue that the concept of unlaws – the negative counterpart of laws – unites many apparently quite separate notions in science, including some that may be drawn upon by practising scientists almost unconsciously. Having once become aware of unlaws, one begins to see them everywhere. It is therefore necessary, or at least helpful, to attempt a taxonomy of unlaws, and in the following sections I will attempt to group them into the main families into which, in my opinion, they naturally fall.

1. SYMMETRY, INVARIANCE, AND CONSERVATION PRINCIPLES

If there is a category in which unlaws enjoy official status it is this. Symmetry and invariance are closely related. The technical definition of symmetry involves the notion of a mathematical group of transformations. More simply, symmetries can be understood as certain kinds of change which preserve a specified property of something. Wallpaper patterns show symmetry, since the pattern is preserved if you move it horizontally a certain distance: otherwise it would be impossible to match the pattern across different rolls. Whereas symmetry represents *change*, an invariant refers to the thing which is *unchanged* under a symmetry group. This independence under the changes imposed by the symmetry group is an example of an unlaw.

In the case of wallpaper, the symmetry group may comprise certain horizontal and vertical displacements, and sometimes, reflection in a mirror. The invariant is the "unit cell" or fundamental component of the recurring pattern. Wallpapers can have complex unit cells: William Morris' "Strawberry thief" design has two birds together with multiple plants, flowers and fruits. Under reflection and translation, this unit generates the whole design.

Different groups give rise to different wall patterns. It can be shown that there are just seventeen possible symmetry groups with two-dimensional patterns. Islamic artists, who were constrained by their religion to a limited number of themes (unit cells) but were permitted to use geometric patterns, explored their full range. It has been claimed that all seventeen symmetry groups are exhibited in, for example, the decoration of the walls of the Alhambra Palace in Granada.

More complex symmetries are of course possible. The Cosmological Principle in physics states that the universe is homogeneous and isotropic: it is invariant under the group comprising all lateral displacements plus rotations; on a large scale, the

[1] Statistical independence is sometimes confused with orthogonality, when two variables have zero correlation. Independence is a more stringent condition: two variables can be orthogonal, but functionally connected and therefore not independent (eg the graph of $y = x^2$ in the range $x = -1$ to $+1$).

universe appears the same at any point in space, and in any direction. A powerful result in theoretical physics, Noether's theorem, tells us that for a physical system, an invariance of this kind always implies a corresponding conservation law – a statement that some quantity is unchanged over time. In particular, the homogeneity of space implies the conservation of momentum, and isotropy ensures the conservation of angular momentum. The invariance of the universe over time gives rise to the conservation of energy. Though traditionally referred to as 'laws', I suggest that conservation principles are more naturally viewed as unlaws. They are of wide application, and have had a powerful impact on physics.

Newton's third law, that action and reaction are equal and opposite, amounts to the claim that action and reaction can be related by a mirror symmetry. At a more complex level, Einstein's fundamental equations of special relativity can also be related to an invariance principle. It is famously true that the velocity of light appears identical to different observers in relative motion to one another. This fact is often taken in physics books as an unexplained assumption, but it appears arbitrary: why should light be so special? Why not, say, take the speed of sound as constant?

There is a more fundamental explanation. Light is an electromagnetic wave. Its veolocity can therefore be derived from Maxwell's equations, which are a complete expression in classical physics of the relationships between electric and magnetic fields and how they change over time. Maxwell's equations correspond to the unit cell in the wallpaper example. Einstein believed that laws of nature, such as Maxwell's equations, should be true for any observer. The assumption of the independence of laws from observers is a very powerful unlaw; it corresponds to the symmetry invariance of wallpaper patterns. From this, it follows that each observer will use the same set of equations – Maxwell's equations – to calculate the velocity of light in their own frame of reference. Identical equations must have identical consequences, and since the velocity of light is a mathematical consequence of these equations, each observer must find the same value for it. No further assumptions are needed.

Our final example in this section concerns the method of dimensional analysis, discovered by the British physicist Lord Rayleigh. The details are technical, but the idea behind the method is simple. Where physical laws can be expressed in terms of fundamental units such as mass, length and time, it is reasonable to assume that the expression of the law should not depend on the particular system used: kilograms and metres should give the same formulae as yards and pounds.

This invariance of form under change of basic units is an unlaw, and one with profound consequences. One can deduce, without knowing anything about the mechanics of pendulums, that the period of oscillation of a pendulum is proportional to the square root of its length. In this example, the method does not tell us anything new, because conventional analysis is powerful enough to give us an exact solution. But the method comes into its own in situations where at a fundamental level, we are deplorably ignorant of how the physics works.

A notorious example is turbulent flow in fluids. On his death bed, Werner Heisenberg said that he was looking forward to asking God to explain turbulence, though he was not sure He would be able to. However, though we cannot yet find exact solutions for turbulent flow, dimensional analysis reliably enables us to find out whether or not in a given situation, the flow will be turbulent. This is done by calculating the so-called Reynolds number: if this is greater than 4000, the flow will be turbulent.

The Reynolds number is one example of a dimensionless parameter. “Dimensionless” means that it has the same value whatever physical units for mass, length and time are used: the number is an invariant under changes of fundamental units. Dimensionless parameters represent a way of gaining an insight into many areas of physics where we are confronted by highly complex systems. As such, they are of great practical value to designers and engineers. One text on dimensional analysis (Massey, 1971) lists over 200 dimensional parameters, concerned with everything from astronomy and meteorology to ship design, each of which can be viewed as a self-contained unlaw. On a purely numerical count, unlaws far outnumber laws.

This is merely a selection of the applications of symmetry in physics. It is, for example, central to understanding the relationships between subatomic particles, a field of active current research. But we must turn our attention to areas where the underlying unlaws are less familiar.

2. UNLAWS AND THOUGHT EXPERIMENTS

Galileo used thought experiments extensively, and herein lies a paradox. Though often described as one of the pioneers of experimental science, it is has been claimed that Galileo did not in fact conduct many of the experiments that he describes. This, strangely, does not seem to matter: his arguments are so compelling that we do not need to witness the experiment; just reading about it is enough to carry conviction. This cannot simply be due to Galileo’s flair for dialectic, though he was certainly a gifted polemicist. His ability to use ridicule against his opponents is sufficient to account for the hatred which he has aroused in the orthodox-minded down the ages. But my contention here is that the true reason for the persuasive power of Galileo’s arguments is that they rely on unlaws.

This is not obvious at first sight, and philosophers of science have sometimes been misled; Paul Feyerabend, who was acute enough to be aware of the lack of empirical evidence, but failed to spot the unlaws, concluded that Galileo was a propagandist who relied on trickery (Feyerabend, 1993). For Galileo’s fans, his thought experiments derive their force through being based on pure logic: but this too is wrong. A single example will illustrate the point. One of the experiments attributed to Galileo which he probably never performed was to drop two balls, one heavy and one light, from the Tower of Pisa and to show that they hit the ground simultaneously. This was in contradiction to Aristotelian physics, because Aristotle had taught that heavier weights would fall proportionately faster than lighter ones.

His refutation is as follows (Galileo, 1638/1914, p. 63). He asks us to grant that if you have two bodies whose natural speeds of fall are different, and you tie them together, the faster one will be retarded by the slower, and the slower one will be speeded up by the faster. Suppose you have a large stone that moves with a speed of, say, eight, and a smaller stone that moves with a speed of four, then if they are tied together, the system will move with a speed of more than four but less than eight. But the two stones together are equal weight to a larger stone than the one that moved with a speed of eight, yet it moves with a speed less than eight. The heavier body moves more slowly than the lighter, refuting Aristotle.

Why does this argument work? Galileo uses two premisses – in fact, two unlaws – in his argument, one stated, the other implicit. The first is that the slower ball will have an effect on the faster ball, slowing it, and the faster ball will have the opposite effect on the slower ball. The second assumption is that an object of a certain weight composed of two balls will behave in the same way as a single ball of their combined weights. The first assumption is, in essence, Newton's third law, that action and reaction are equal and opposite. The second may not be precisely true, since air resistance may differ for a single and a combined object. But in the conditions of the thought experiment, we have an intuitive conviction that this objection will make little difference.

Historically, Galileo did not originate the thought experiment: he had two forerunners. Archimedes used the method with great ingenuity to prove the principle of the lever. He was followed in the sixteenth century by a Dutch investigator, Simon Stevin. To motivate Stevin's most famous discovery, we may begin with the commonplace observation that it is harder to pull a loaded wheelbarrow up a steep slope than up a gentle incline. Stevin showed that this common experience could be made exact, in a surprisingly simple way (see Mach, 1919, pp. 24-28 for a fuller discussion).

Stevin imagines a chain loosely draped over a wedge shaped support, represented in figure 1 by the triangle ABC.

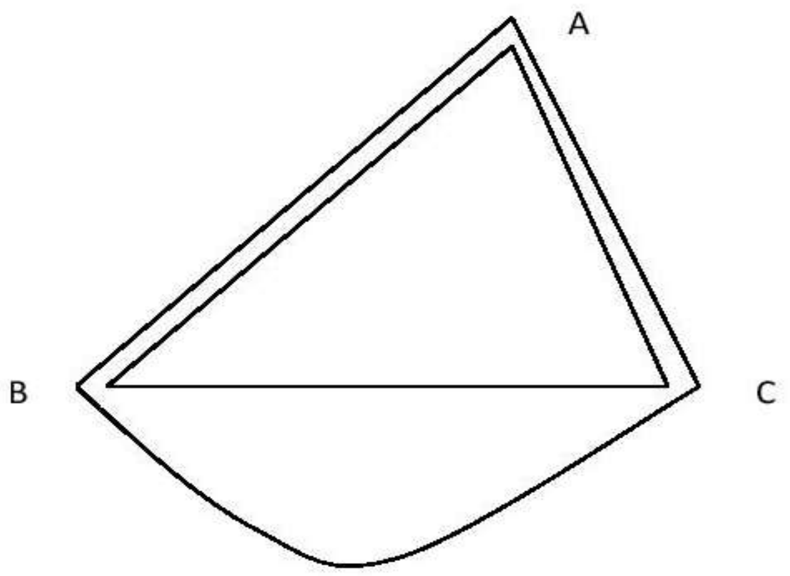

Figure 1 Stevin's demonstration

The bottom portion of the chain hangs freely from the horizontal edge BC. From the symmetry of the situation, the weight of the portion of the chain hanging loose from the edge BC must exert the same force at B as it does at C. Moreover, such a chain must remain at rest: if it were to start to move round the wedge, say in the clockwise direction, there is no reason for it ever to stop. We would in effect have a perpetual motion machine. Stevin claims that this is impossible.

Now focus on the link at the apex A of the wedge. We know from the previous argument that this link cannot have any tendency to move. This implies that it must be acted upon by equal forces coming from the chain draped over the AB, and from the chain along the side AC. Therefore the heavier length of chain along AB exerts the same force at A as the lighter length along AC (the chain dangling from BC makes no difference as it affects the two sides equally, as we have seen). In wheelbarrow language, a heavy wheelbarrow on resting on AB would require the same force at A to hold it steady, as a light wheelbarrow resting on side AC.

We now have our required connection between steepness of slope and force. Put into mathematical language, this amounts to the statement that the force of gravity on an object on a frictionless plane extending a fixed height from the ground is proportional to the object's weight and inversely proportional to the length of the slope.

This is a substantial result to be deduced from nothing more, apparently, than simple logic, together with the assumption that it is impossible for the chain to go round for ever. Mach (1919) suggests that this result is a result of 'instinctive knowledge', arising out of our 'accumulated experiences' of nature. He concludes: "It is a peculiarity of instinctive knowledge that it is predominantly of a negative nature": Mach seems to be on the verge of defining unlaws as a category. Stevin's assumption is of course a consequence of the conservation of energy, which in turn is based on the invariance of the universe over time, relying on an empirical unlaw.

I will briefly mention another application of unlaws in thought experiments, namely scaling arguments. From our schooldays, we may recall such questions as: if two men dig three trenches in three days, how long does it take six men to dig six trenches? Solving these problems requires the assumption that the rate of trench-digging per man is independent of the number of men present, which is an unlaw. Scaling arguments are an area in which Galileo came into his own. In his second book (Galileo, 1638/1914) he used the scaling method to such effect that it enabled him to lay the foundations for modern statics and dynamics. Again, Galileo's arguments are not supported by experimental data, yet they are persuasive in the same way that his refutation of Aristotle is persuasive, and for the same reason: they depend on unlaws.

3. UNLAWS AND EXPERIMENTAL DESIGN

Perhaps the most sensitive and remarkable measurements ever conducted are those carried out by the Laser Interferometer Gravitational-Wave Observatory (LIGO), which has detected events such as the merger of two black holes. LIGO is so sensitive that elaborate precautions are needed to filter out disturbances on earth, to enable it to detect genuine gravitational signals from space. It does this using a pair of interferometers 3000 kilometers apart. Processing the data depends on an unlaw: the assumption that vibrations in one place due to local effects are completely independent of local vibrations in the second site. When the results are processed, vibrations which are detected at only one site are rejected as interference; signals that are identical in both locations are retained as indicating a gravitational event in space.

Studies in psychology are notoriously subject to such disturbances in the data, and particular precautions need to be taken to avoid its effects. People differ between themselves; even the same person will behave differently on different days. Academic papers in psychology follow a standard format, one aim of which is to enable other researchers to replicate the results[2] despite these difficulties. The message of such a paper is this: "if you follow the procedures we followed, you will get similar results." This is to claim an unlaw: the results will be independent of the laboratory conducting the experiment, and of the time and place in which it is carried out.

But this independence is not easily gained. In order to ensure it, a well-conducted experiment should eliminate two kinds of error: random and systematic.
To reduce random error, standardising the way an experiment is administered to different participants – for instance, fixing the distance and brightness of a visual display – is often essential, and these details will be given in the report of the results. Without this, attempts at replication may fail because they will not be repeating the original experiment sufficiently closely.

But no experimental report can ever be a complete account, which would require a second by second record of everything that occurred, however trivial. The report implicitly assumes that details that are unspecified, and which may therefore vary in replication, are not vital. We take it for granted that things like the colour of the experimenter's shoes, or the position of the planets at the instant of measurement, are irrelevant. If we call these "ignorable variables", we are saying that the results are independent of these variables, in other words, *every ignorable variable is the subject of an unlaw*. And so around every experimental report there is an invisible cloud of unlaws, swarming as densely as gnats on a summer's evening. And whether or not an unlaw is acknowledged, its existence is essential. Every ignorable variable implies the truth of a corresponding unlaw, but if the unlaw turns out to be false, we are in trouble. A variable which significantly affects the outcome of an experiment but which is overlooked, is known as a confounding variable, and may have disastrous effects on the validity of the results.

The principle known as Occam's razor can be recast in the language of unlaws. In the form "nature operates in the shortest way possible", it goes back to Aristotle. The usual wording is "it is vain to do with more what can be done with less". Applied to experimental hypotheses, this suggests that the number of causal factors included in a hypothesis should be minimized. This means that the number of causal factors *excluded* from a hypothesis should be *maximised*. But to state that a causal factor C is absent from a hypothesis accounting for an effect E is equivalent to stating that C and E are related by an unlaw. So Occam's principle becomes: "for any given hypothesis,

[2] This aim is not always successfully achieved. An internet search for 'the replication crisis in psychology' will indicate the extent of the problem.

maximise the corresponding set of unlaws." But we must be careful not to go too far, and wield our razor over-zealously (see Ball, 2016).

All aspiring medical and psychology students are taught about the threat of systematic bias in experiments which may arise if you are taking two groups of participants and using them as "treatment" and "control" groups. The most effective way to test an experimental effect is to use a randomized controlled trial. A pool of participants is allocated randomly to receive, or not receive a particular treatment. It is essential that there should be no systematic difference between the two groups at the outset, otherwise the results may be due to the group difference and not the treatment. The way this is usually achieved is to use random allocation, in which the decision to put a particular participant in the treatment or control group is decided by chance.

The usual method involves a random number generator, such as can be found in any spreadsheet program. We first list the participants in any order. This order does not matter: it could be alphabetically by name. Suppose they are Alice, Dick, Emily and Tom. To Alice one allocates the first random number found, say 0.853, to Dick, the second number (0.452) to Emily, the third (0.227) and to Tom the fourth (0.696). The random numbers are then rearranged in their own numerical order (0.227, 0.452, 0.696, 0.853), and the participants to which they correspond are listed in the same order (in our example this gives Emily, Dick, Tom and Alice). The process scrambles the original order of participants. Now we can allocate Emily and Dick to the treatment group and Tom and Alice to the control group. With 60 participants one might allocate the first 30 participants in the scrambled order list to the treatment group, and the second 30 to the control group. How do we know that this allocation will be free of systematic bias? Because an unlaw states that the process of generating random numbers in a computer is by its nature statistically independent of the process of listing participants in alphabetical order. The computer is blind to their identity.

Unlaws are subtly involved in more complex experimental setups, too, which are often based – whether or not the experimenters are aware of it – on John Stuart Mill's "canons of experimental enquiry" (Mill, 1875, pp. 448-471). To introduce the canons, I will illustrate their use in figure 2.

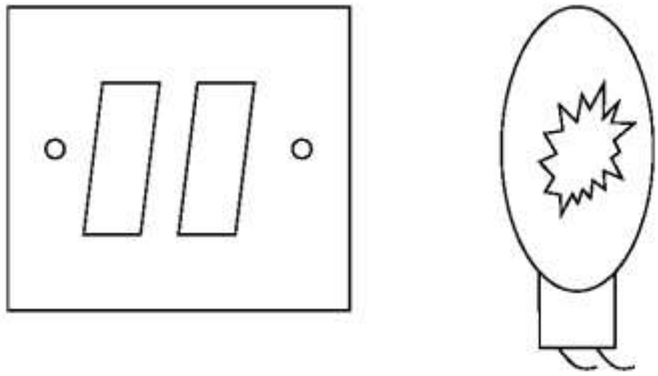

Figure 2 Mill’s methods of agreement and difference

Imagine that we have reason to believe that the double rocker switch on the left, with both switches in the “up” position, has some causal link with the light bulb on the right, which we assume initially to be lit. The obvious next step is to operate the switches and see what happens to the light. Suppose we flick the left hand switch down and up again, and nothing happens. Now we flick the right hand switch down and the bulb goes off. When we flick it up, the bulb goes on again. Just to be sure, we flick the left hand switch down and leave it there; the light remains lit as we already know. Now we try the right hand switch and we find it has the same effect as before, of turning the light off, and then on again.

It is evident that the right hand switch, and it alone, causes the light to go on and off. Operating the left hand switch while ignoring the right hand switch, and seeing no effect on the bulb is essentially Mill’s “method of agreement”: the right hand switch is unchanged, so its positions agree, and the bulb stays lit, so its states also agree. The right hand switch demonstrates his second canon, the “method of difference”: both the positions of the switch, and the states of the bulb, differ. The method of agreement means we can rule out the left hand switch as causal. If we already knew that *one* of the switches was the control switch, we would now be able to assert that it was the right hand one, by elimination. But if we were not certain that one of the switches was the control, the method of difference would remove our doubts. So our manipulation of both switches – what Mill called the “joint method of agreement and difference” – enables a complete analysis of the causal links between the switches and the light.

Note that the canons of agreement and difference operate to demonstrate an unlaw and a law, respectively. The unlaw is that the position of the left hand switch does not correlate with the light being on or off, and the law is that the position of the right hand switch does so correlate. The information given by this “experiment” can be summarised in Table 1.

Table 1 Causal link between switch positions and light responses

	Left switch up	Left switch down
Right switch up	ON	ON
Right switch down	OFF	OFF

In this presentation, the law is represented by the *difference* between the rows (ON – ON is different from OFF – OFF) and the unlaw is represented by the *agreement* between the columns (ON – OFF, and ON – OFF). This illustration of the row/column dichotomy between laws and unlaws suggests an analogy with the weft and warp structure of fabrics: both warp and weft are essential.

It is not always appreciated that Mill’s joint method of agreement and difference is central to many experimental designs. A single example will illustrate the point. A group of French scientists (Scheunemann et al., 2019) has shown that female fruit flies get a boost in their long term memory thanks to a molecule found in male fly semen. This ‘sex peptide’ binds to fruit fly sperm, and travels from the female reproductive tract to the brain. To test their theory that the sex peptide is responsible for the memory effect, the team conditioned females by pairing certain smells with electric shocks. They were then exposed to smells that were, and were not associated with shocks. Flies that had mated remembered to avoid smells linked with shocks, but those that had not mated, forgot after four days.

This experiment shows the method of difference in action. But the group did more than this: they extended the experiment by invoking the method of agreement. It might be objected that the memory improvement was due not to the sex peptide in the sperm, but to some other chemical in it, or to another effect of mating. To rule this out, females were mated with males modified to lack the sex peptide, and these were found to show no improvement in long term memories. Females which had not mated with a male but were injected with the peptide, showed the improvement. The findings can be summarised in the following table.

Table 2 Causal link between sex peptide and memory in female fruit flies

	Females were mated	Females were not mated
Sex peptide present	IMPROVED MEMORY	IMPROVED MEMORY
Sex peptide absent	NO IMPROVEMENT	NO IMPROVEMENT

This table has exactly the same pattern of responses as in table 1 above. It shows that the act of mating does not in itself produce better memory, aside from transferring the sex peptide. Therefore, the sex peptide is truly the factor responsible for the effect.

The power of this result is that it combines an unlaw (no effect of mating *per se*) with a law (positive effect of presence of sex peptide).

There is nothing particularly unusual about this study. The principle is of wide application in the life sciences: it can be shown for example that the joint method of agreement and difference is the foundation for the validity of Koch's postulates, which is the classical method to determine whether an infectious agent really is the cause of some disease.

4. UNLAWS AND UNREALITY

Hollywood knows that a good way to invoke a threatening atmosphere is to use a laboratory setting. Real life laboratory experiments are, if not sinister, at least unnatural environments. Scientists generally wish to study individual processes in isolation from the confusing medley of sights, sounds and feelings which is the outside world[3]. Some philosophers criticize experimental science precisely on the grounds that laboratory testing is unrealistic. How can anything arising out of such a controlled environment be of any relevance to the rich diversity of human experience? How, in technical terms, can such experiments achieve ecological validity?

This question has two answers. The first, simpler reason for the value of artificial laboratory environments involves the idea of hypothesis testing. It is a standard principle of scientific research that it should be 'hypothesis driven'. In its most sophisticated form this involves putting all possible hypotheses into competition, which will enable us to eliminate the false alternatives and settle on the true one by comparing the actual outcomes with what the different hypotheses would predict.

The 'acid test' with which jewellers distinguish gold from base metal is an artificial procedure, but I doubt whether any philosopher would reject it on the grounds of its artificiality. Creating an acid test for hypotheses may also involve artifice, but this need not matter: we require only that the hypotheses under test are able to predict the result of an experiment in such conditions. In fact the lack of realism may make this task easier. Galileo was once visited by a fraudster claiming to have invented a machine for communicating over long distances. The man asked Galileo for money to send him to Pisa, so that he could demonstrate his machine by sending a message to Galileo in Florence. Galileo told him to go first to the room next door, and demonstrate his machine by sending him a message from there.

The second answer is that complex natural phenomena, such as a leaf blowing in the wind, are often a combination of simpler processes. Nobody expects scientists to come up with a comprehensive theory devoted to explaining the drift of autumn leaves. To find regularities that can be described by laws, one needs to isolate and study independently the separate influences on a leaf. Finding that in a vacuum, all objects, including leaves, fall with a constant acceleration, might be a part of this. The study of the force exerted by air resistance, and how this depends on an object's shape and relative velocity, would be another aspect. In the case of our leaf, its movement is

[3] Note, however, that laboratories are not always enough. Ethology, the study of animals in their natural environment, is essential to a full understanding of their behaviour, just as sociology and anthropology complement experimental psychology. Science is a broad church.

determined by two forces: gravity, and air resistance, together with wind velocity. These forces could be calculated separately and then added. This is valid because the effect of one force is independent of the size of the other force.

This independence is, of course, another unlaw[4]. The additivity of the forces acting on an object is just one instance of how separate processes can be studied – artificially, if you will – and then combined to achieve a realistic outcome. Additivity[5], meaning that there is no interaction between the forces, is a characteristic of this class of unlaws. Additivity, where it applies, is an essential accompaniment to the laws of physics, and as important as the laws themselves. It is a failure to understand this that vitiates the criticisms of, for example, Nancy Cartwright (1983, pp. 57-63).

In the absence of additivity, interaction effects appear, and everything becomes more complicated. The effect of a cocktail of drugs on the human body cannot be found from calculating the individual effects of the chemical components of the drugs on the individual organs of the body and adding the results: in such areas, Cartwright's reservations are fully justified. Moreover, in many areas of science our understanding is partial and limited, and different models may have to be used in different situations. Scientific theories are not like a Swiss penknife; they are more like the hammers and screwdrivers on a carpenter's bench. This does not invalidate these methods any more than its inability to drive in screws invalidates a hammer. We accept that human judgement is necessary in the practice of medicine: to a surprising degree, it is also needed in physics. In short, exact science is not an exact science.

5. UNLAWS AS THE SOURCE OF LAWS

Unlaws also lie at the heart of a historical argument between two fundamentally different ways of looking at science, whose echoes continue to this day. It was most clearly expressed in the dispute between the followers of Isaac Newton and René Descartes. Newton considered that the job was done when an accurate mathematical description had been given of the way objects behaved in the universe, such as his law of gravitation. But Descartes found Newton's account incomplete. He demanded that a valid scientific explanation should describe not only *how* two objects attracted each other, but *why* they did so – a complete theory of gravitation should explain the *mechanism* by which the attractive force exerted its effects.

In some accounts, Descartes is judged to have had the better of the argument. Newton is seen as the arch empiricist, who, in the typically slipshod English tradition, did not bother too much with the logic of an argument as long as his theories gave the right answers in practice. Descartes is presented as the man who was asking the right questions, though ahead of his time, and who would have been delighted with Einstein's theory of general relativity as providing the explanation which Newton's ideas lacked. Newton should never have been content with 'action at a distance'; moreover, he turned out to be wrong even by his own criterion of providing a correct mathematical description of the phenomena. Newton's theory fails to account for a

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[4] And it can be shown to be a mathematical consequence of the invariance of the laws of mechanics under rotation, reflection and similarity transformations.
[5] More usually referred to as 'linearity'. Scientists dread nonlinearity like a vampire dreads garlic.

host of effects, such as the precession of the orbit of Mercury, which are correctly described by Einstein's theory.

I wish to present another way of seeing Newton's empiricism. Newton was wrong in the mathematical sense that his theory of gravitation is only an approximation to the truth, though for nearly all practical purposes it is adequate. But, I will argue, he was not illogical. Newton referred to a process of deducing propositions from phenomena which he called 'induction'. Induction involves reasoning from the particular to the general, in other words, the process of deriving general statements from individual sets of empirical data. Newton did not explain in sufficient detail why he thought induction was valid, and subsequent philosophers of science have agreed, if they agree on little else, that induction is untenable as a method of finding the truth.

David Hume was the first philosopher to point out that pure induction can give us no sure knowledge, an insight taken up and developed by Karl Popper. Popper produced an example to prove that empirical data could never justify a general proposition derived from these data, no matter how many confirmatory instances of the proposition are obtained. Suppose that English naturalists observe a large number of swans and note that they are all white. By induction, the naturalists claim that all swans are white, and further tests confirm its truth. But then European explorers land on Australia and find has swans in every way similar to those in Europe, but black in colour. Despite confirmation by thousands of instances, the proposition "all swans are white" turns out to be false.

This argument, presented with Popper's characteristic force and persuasiveness, appears final. But now consider a similar statement: "all electrons have a mass of 9.109×10^{-31} kilograms". This statement is true[6], or at least, is accepted as such by physicists. But applying Popper's white swan argument, how can we be sure? New discoveries about subatomic particles appear constantly. Might we not at some future time be presented with an electron having, say, twice this mass? One answer would be, that if we found such a particle, physicists would not call it an electron: they would give it a new name. But would this not be cheating? If one were to defend the statement "all swans are white" on the grounds that a so-called 'black swan' was not a swan at all, because it was the wrong colour, then the original statement is no longer a claim of a factual law, but part of the definition of a swan.

In fact, it seems to be the case that subatomic particles obey different rules than macroscopic objects such as swans. It would indeed be cheating to rule out black swans as swans, but it is not cheating to rule out overweight electrons as electrons. There seems to be a qualitative difference between the subatomic realm where quantum laws prevail, and the world of what J. L. Austin called "middle-sized dry goods". If on this basis we accept that all electrons are identical, then we can obtain a general statement about electrons by simply examining one of them, finding a property that it possesses, and then making a general statement to the effect that every electron has this same property. So we can establish laws, at least regarding electrons, by induction. By the arguments of Descartes we have no right to do this, unless we explain why an individual electron should have these properties. However, scientists

[6] True, that is, if we accept it as giving the mass of an electron to within the level of precision implied by three places of decimals.

seem entirely unperturbed with the claim that every electron is identical to every other electron, not only in its mass but also in its charge, and spin. Most scientists, in this respect, are Newtonians and not Cartesians[7].

The method of induction applied to electrons involves generating a law from a combination of an empirical observation and an unlaw. The unlaw is: “the identity of an electron[8] is independent of its properties”, which is equivalent to saying “all electrons have the same properties”. The empirical observation is “this electron here has a mass of 9.109×10^{-31} kilograms”, and the law formed by combining these two statements is “all electrons have a mass of 9.109×10^{-31} kilograms”.

There is no space to discuss Newton’s logic in detail, which is contained in his four ‘rules of reasoning in philosophy’ (Stanford Encyclopedia of Philosophy, 2014). In what follows, I will merely lay out what I believe is the substance of his argument, as I interpret it. Rule III is the key assumption. It claims that certain properties of bodies are identical for all bodies, just as certain properties of electrons are identical for all electrons. This implies for example that if two bodies with given masses at a given distance apart are found to attract one another with a certain force, then any two bodies with those masses placed at that distance will attract one another with that same force. This is an unlaw, because it states that the all other properties of the bodies are irrelevant to determining the force between them.

This is the first part of his argument. The second part is that he finds, using the solar system as an example, that bodies attract one another proportionately to the inverse square of the distance between them. This is the empirical part. But as we saw above with the electron, the combination of an unlaw with an observation can give rise to a law, by simple logic. Therefore, Newton can conclude that his observation is general, and state a ‘universal law of gravitation’.

Of course, Newton’s conclusion was wrong, but this was due to the failure of the second part of the argument: the empirical data were not precise enough. The first part, the unlaw, is unaffected by this, and I am not aware of any scientist who would dispute it. Philosophers have overlooked the first part of Newton’s reasoning, which was, and remains, unchallenged.

6. UNLAWS AND DIVERSITY

Imagine a population of Martians who move around on tripod-legs and possess antennae. The population shows the usual range of large and small individuals. Suppose that for Martians living in the northern hemisphere of their planet, the length of their legs and of their antennae is perfectly correlated, so that they obey a law of the form $L = k.A$, where L is leg length, A is antenna length, and k is a number which takes the same value for each Martian. If the values of L and A for the Martian

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[7] Most, but not all. The physicist Geoffrey Chew claimed that it should be possible to deduce the properties of subatomic particles by logic, from the demand that the laws of nature must be self-consistent. His so-called “bootstrap” method scored some successes, but ultimately failed to gain general acceptance.

[8] By “identity” I mean any way of distinguishing a given set of electrons: this one here, that one over there and so on. Whichever one I choose, I find it makes no difference to the properties that I measure.

population were plotted as a graph, the points would all lie on the line Y = k.X. Knowing that the law held, and the value of k, would give us useful information about the population, and would certainly be of interest to Martian biologists. Call this population I.

However, now assume that another race of Martians exists, population II, occupying the southern hemisphere, separated from population I by an impassably hostile equatorial zone. For them, L and A are completely independent of one another. This means that these Martians can be found with any combination of short or long legs, and short or long antennae. The usual approach of the life sciences would have little to say about population II. The lack of correlation would be seen as an uninteresting fact, scarcely worthy of mention. However, with an awareness of the value of unlaws, we can examine the situation differently.

Suppose that in population II, the distribution of leg lengths is uniform between 3 and 5 metres, and that antennae are uniformly distributed between 1 and 2 metres in length. If the values of leg and antenna length are plotted on a plane for population II, the points will be uniformly distributed in a rectangle. This distribution expresses a fact about population II which in its way is as much a characteristic of it, as the straight line graph is of population I. In fact, the distribution is an indication of the diversity of population II. This fact is an important one, not for describing individual Martians but for characterising population II as a whole.

Another way of looking at this is that the correlation in population I, strongly suggests a common causal mechanism for determining the length of both legs and antennae; possibly that there is a common link connecting both leg and antenna length with the age and genetic makeup of the individual. The Greek philosopher Democritus is reported as saying: “I would rather discover one causal law than be king of Persia”, and scientists to this day are often strongly motivated by the prospect of finding causal mechanisms. Moreover, the study of zoology has traditionally focused on the characteristics of individuals rather than populations.

With population II, on the other hand, we have a *lack* of causal mechanism connecting legs and antennae. It might be thought difficult to publish a discovery concerning the absence of mechanism: this would appear to be a situation without interest. From the point of view of a population ecologist, on the other hand, the reverse might be true.

Diversity in a population sometimes reflects an evolutionary pressure to fully occupy the ecological niches available in an environment, and it may well be that a more varied population has greater potential resilience in surviving external shocks and challenges. There may be some unforeseeable combination of leg and antenna characteristics that would enable at least some population II individuals to endure a Martian catastrophe, whereas the more restricted population I would be wiped out. If it turns out that the southern but not the northern hemisphere is subject to repeated environmental shocks, this might explain the difference between the two populations.

Diversity is known to be a characteristic of successful teams, which bring multiple skill sets to a problem. Group-think, conversely, is the consequence of having a set of individuals cast in the mould of the leader: the outcome, from the Crusades to the Challenger disaster, is often catastrophic. One might summarise this aspect of unlaws as follows: whilst laws describe limitation, unlaws describe diversity, and diversity is frequently desirable.

Ignoring unlaws leads to a mindset where diversity may be undervalued. One example of this occurs in psychology research into people with neurological differences, such as individuals with autism. Researchers often seek to show that autism is associated with a functional deficit of some kind. Finding such a group difference amounts to a law: autism is associated a specified difference in ability. This leads to reporting bias, since it ignores the need to identify unlaws as well as laws. This tendency is made worse by the standard statistical procedure of null hypothesis significance testing (NHST: see, e.g., Allen (2017)). The null hypothesis is the statement of an unlaw, but the procedure does not allow for any positive conclusion in favour of the null hypothesis.The result is the so-called 'file drawer problem', meaning that research which fails to show a significant group difference is often deemed unpublishable, giving the impression that autism is defined in terms of deficits.

This is no mere theoretical possibility, and can have real implications for the treatment and well-being of people on the autism spectrum. In the early 2000's my own research involved studying the effect of music on people with autism spectrum conditions. At that time some researchers were arguing on a priori grounds that autism would be associated with a failure to understand or be moved by the emotional content of music. I subsequently discovered through personal communication that one of the people who had put forward this hypothesis had actually carried out research which showed that no such differences existed. But this important result remained unknown to the wider community: the researcher had abandoned the study on the grounds that it would be hard to get such negative results published. The misconception therefore continued, and even spread, until growing evidence to the contrary forced a rethink. A system which fails to recognise the value of unlaws makes such errors far more likely.

7. CONCLUSION

One of the objections that humanists make to science is that it attempts to force everything into a straitjacket, where iron laws determine events in a clockwork universe, and that it ignores the richness of the private experience of life possessed by different individuals. I have argued elsewhere that the arts and sciences share important features (Allen & Heaton, 2018). However, science may present itself as interested only in necessity, and ignorant of contingency and diversity. Scientists sometimes indeed appear blind, or at least one-eyed, in their pursuit of regularity and generality, and in their lack of interest in uniqueness. This is a result of a scientific training which overlooks the unlaws in which this diversity resides. In psychology, in the case of music and autism but also elsewhere, this style of thought raises serious ethical questions about the way conclusions are drawn from research and applied to the treatment of people.

The drive to examine the laws which underlie the regularities in the universe, in which every particle is connected with every other particle, is admirable, but it can lead to a habit of mind where the world is seen as deterministic, and where individual free will is obscured. E. M. Forster's famous words "Only connect" are often cited, but few people seem familiar with the full passage in Howards End from which these words are taken: "Only connect! That was the whole of her sermon. Only connect the prose and the passion, and both will be exalted, and human love will be seen at its height. Live in fragments no longer." Science is already familiar with the prose: we need to add the element of passion by becoming aware of the value of diversity, and I propose that we begin by appreciating those dark materials comprising the deepest foundations of science, the unlaws.

Laws and unlaws are the weft and warp in the fabric of nature. Like children, we are drawn to movement and colour: we gaze on the shuttle as it flies to and fro, creating patterns out of the air as it carries the weft through the warp. But without the warp there would be no fabric, and without unlaws there would be no science. Fully to appreciate the world, we must learn to understand both.

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