desideratum of any account of moral goodness, and on this we might have an argument. My point is that Bloomfield's winning that argument is a *prerequisite* of his analogy convincing an opponent (though, of course, it won't be sufficient, for the sceptic might be bothered by quite different things about moral goodness that also appear to be disanalogous with health). Moreover, if it is (2) that Bloomfield wants to endorse then one is left wondering why his chosen analogy is with the property of *health*, which at least stands a chance of fitting the bill in this respect—why not instead try to establish moral realism via analogy with an 'innocent' property that clearly makes no desire-independent demands upon us—say, *being Norwegian*?

Certainly, thinking carefully about the property of healthiness is a useful exercise for anyone giving their attention to the problems of metaethics—and for that we must be grateful for Bloomfield's lively and stimulating contribution—but it remains doubtful that the outcome of the exercise is a decisive conclusion in favour of moral realism. In the end (to push a metaphor), I felt like someone interested in, and doubtful of, the existence of unicorns who had just been shown a live rhinoceros and been told 'You don't question the objective existence of *that*, so why do you persist with this doubt about unicorns?'

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The Dappled World: A Study of the Boundaries of Science, by Nancy Cartwright, Cambridge: Cambridge University Press, 1999. Pp. 247. P/b £13.95, H/b £50.00.

Nancy Cartwright resists the picture of science as a monolithic whole, with the laws of physics as basic, and with subsidiary domains of chemistry, biology, economics, psychology, etc. Not only is she opposed to scientific reductionism, and to the idea of 'fundamental' elementary particle laws in physics underlying everything else, but she is sceptical about whether all or even the majority of events in the world fall within any scientific domain. A thousand dollar bill which drifts towards the ground in St Stephen's Square (Neurath's example, p. 27) may do so in a chaotic or otherwise completely unpredictable manner, not subject to any law of physics because there is no dynamical model for the wind. Cartwright's arguments are persuasive and her point of view is attractive and very different from the majority opinion in philosophy of science today.

Whether Cartwright is right, or whether Cartwright is wrong, is another matter. Her arguments need to be picked up, turned over, and examined carefully. My assessment is that all readers will find something to agree with, and some may be convinced. But the old fundamentalism, the drive to universality, the noble search for a single theory of everything, struts out and dies hard.

Cartwright does not find scientific laws lying around, so to speak, waiting to be revealed. Instead we have to work hard to create what Cartwright calls 'nomological machines' which unearth them. No nomological machine, no law. For this reason all laws are *ceteris paribus* laws, the restrictive conditions on them being dictated by the machines. So precise are the specifications for building these machines, and so demanding are the requirements for shielding them from extraneous interference, that in many cases one observation suffices. So much for scientific induction and Hume's doubts, of which more later.

The other side of the coin, of course, is that a scientific law revealed by a nomological machine holds only in a small and restricted domain. Laws are true only in their domain, not universally. Science reveals a patchwork of such domains, generally unrelated to one another, with some overlaps. Do they collectively cover the total area? In all probability not. To repeat, Cartwright believes that all laws are *ceteris paribus* laws, and that the existence of unrestricted, universal, fundamental laws is a myth. She also believes that a second, deep-seated reason why laws are restricted by ceteris paribus conditions is that they disclose a *capacity* or power in nature. For the exercise of this capacity specific conditions must be met, without which the capacity would be impeded. Aristotelians call these capacities or powers *natures*, and Cartwright believes it is time we dropped our prejudices against Aristotelian science and acknowledged that the role of science is to study the natures of things by creating conditions in which these natures produce observable effects.

> If we consider any particular experiment, it may seem that the equipment we move about, the circumstances we contrive, and the properties we calculate away are ones that can be described without mentioning natures. But in each case, what makes the arrangement of equipment in those particular circumstances 'ideal' is the fact that these are the circumstances where the feature under study operates, as Galileo taught, without hindrance or impediment, *so that its nature is revealed by its behaviour*. (p. 84, my italics)

If what Cartwright says is on the right track, then we have come full circle since the scientific revolution of the 16th and 17th centuries. Aristotelian science need not, if we follow her line, be based either on uninformative trivialities or occult unknowable powers, as caricatured by Molière in *Le malade imaginaire*. When the nature of a physical thing is revealed and its capacities exercised, then those powers are no longer occult, they are visible (p. 84). It would be astonishing if Aristotle, reviled by scientists from 1600 to 2000, should be reborn in the new millennium. If Cartwright has her way, he will be.

Now to more detailed examination of the book's various theses. Because the author's general position cannot be sustained or even fully understood without looking in detail at applications of her ideas to particular cases, I shall proceed by presenting and examining a number of nomological machines, some discussed by Cartwright, some new. In each machine, the key concepts to look for are *model*, *capacity, nature, operation, shielding, occurrent property, law,* ceteris paribus *condition, domain, intervention*. Discussion of these ideas will reveal the originality, the distinctiveness, and the diffuse character of the author's insights.

Nomological machine 1. Fibre optics.

When a laser emits a pulse of coherent light down a glass fibre, the natural tendency of the pulse is to broaden as it travels down the fibre. Eventually the pulses smear into one another and the information they carry is lost (pp. 30, 34, 118–9). But if the intensity and frequency of the laser are suitably adjusted it causes a shift in the index of refraction of the optical fibre, and creates a new theoretical entity called a *soliton* by lowering the frequency of the leading edge of the pulse and raising that of the trailing edge. Light solitons are pure artefacts, and they have the capacity to keep their shape and carry information for thousands of kilometres. Would they exist outside of the nomological machine that creates them, shields them, and permits them to exhibit their powers? Doubtless not. The laws they obey hold true only within a restricted domain created by human intervention.

NM 2. The planetary system.

In contrast to fibre optics, the nomological machine which generates the laws of motion of the planets exists in nature (pp. 50–2, 57, 156). It may seem odd to think of a *machine* as responsible for the laws, as opposed to, say, nature in general. But consider the Ptolemaic, Copernican and Keplerian models which served as successive blueprints for Newton's mechanical machine, the insight needed to construct them, and the shielding conditions needed to keep the mechanism operating. Suppose that Kepler had lived not on earth but on Saturn's moon Hyperion, which because of its irregular shape tumbles chaotically instead of rotating smoothly (C. Murray, 'Is the solar system stable?', *New Scientist*, 1989, Nov. 25, pp. 60–3). Not being able to predict where the sun would rise tomorrow on the basis of where it rose today, Kepler would have been incapable of formulating Kepler's laws. 'But would Kepler's laws not have held regardless?' Well, suppose all the planets had tumbled chaotically, and travelled in irregular orbits which because of the 3-body problem were not Turing computable. In the absence of any nomological machines, would the universe still be governed by universal law? Cartwright says no. The regular functioning of the solar system is subject to delicate constraints and boundary conditions, without which there would be no lawlike operation and hence no law.

Newton's laws unify Kepler's, and Cartwright does not deny this. What she does deny is that Newton's law of gravity, properly considered, is a *regularity law*. It is not an assertion of a Humean regular association between occurrent properties such as *mass*, *distance*, and *motion* (p. 52). Rather it asserts the existence of a *force*, that is, gravity, which is not an occurrent property but an Aristotelian power or capacity that in different settings produces a variety of different kinds of behaviour. (Consider black holes, and the orthogonal jets of gas and radiation emitted by pulsars.) To view natural laws as based on uniform regularities of occurrent properties, inferred by induction, and to view them as based on the unimpeded operation of a natural capacity, exercised within a nomological machine, are two very different things.

NM 3. Electrostatic Coulomb forces.

Coulomb's law describes a capacity that a body has *qua* charged, that is, to attract opposite and repel similar charges. Since charged bodies also have mass, a nomological machine is needed to separate electrostatic from gravitational forces and to infer the attractive and repulsive capacities of a charged body *qua* charged (pp. 53–4, 59, 65, 67, 82–4). We build the machine to reveal the behaviour of the charged body, even though in its operation both gravitational and electrostatic forces are at work. Millikan's device to measure the charge of an electron is a case in point: the rate of fall of minute oil droplets through air is measured, and deviations recorded when a positively charged plate is introduced above them. Yet charge, though a power or capacity, is more than simply a capacity to attract or repel. Contrast an everyday capacity or disposition like irritability (p. 54). Charge can be ascribed to a body independently of its ability to attract or repel; irritability on the other hand is nothing more than the tendency to manifest irritation, and for this reason is described by Cartwright as a disposition rather than a capacity or nature (pp. 54, 59, 64). An Aristotelian nature is not exhausted, like irritability, by a one-dimensional display. Nor is it describable in the vocabulary of occurrent, measurable properties linked together by regularity laws. If two masses attract each other, it depends entirely upon the circumstances what observable motion occurs (p. 65). A force is a capacity to cause motion in bodies, but how and whether and in what circumstances that capacity results in motion requires a nomological machine.

NM4. The twins paradox.

The nomological machines discussed in *The Dappled World* generally concern matter, or light, or economic behaviour, that is, the contents of the world rather than the space-time framework that contains them. A different sort of machine can be devised, however, to probe the structure of the world as distinct from its capacities.

Let a spaceship be constructed for a journey to a nearby star, say Sirius about five light-years away. A motor force of only 1g, applied for a year or so once the ship is outside the earth's gravitational pull, will accelerate it to a velocity of 0.9*c*; it then coasts around Sirius and returns towards earth. A year from home the motors are started again in reverse, and the ship comes to rest near Bakersfield California after an absence of twelve years terrestrial time. For the space travellers, however, the elapsed time is only eight years. This nomological machine has revealed not only that a return journey of ten light years in distance can be accomplished in twelve years with only modest acceleration, but that the elapsed time for the travellers is considerably shorter than this. (Thanks to Paul Churchland and John Trischuk for discussion.)

In contrast to the other examples discussed in the book, the 'laws' relating to space-time structure which the nomological machine reveals are indeed universal, cannot be shielded against, and have as their only *ceteris paribus* clause the condition that the earth follow a geodesic and the spaceship not. Both require active intervention. In addition to 'capacity' laws therefore, which reveal the natures of objects, Cartwright needs 'structural' laws, which reveal features of the space-time framework. Both, of course, depend on nomological machines for their disclosure and perhaps even (if Cartwright is right) for their existence.

NM 5. Chance set-ups.

Not every nomological machine reveals an exceptionless law, in which a given effect is produced 100% of the time. Most laws, in fact, are probabilistic rather than deterministic. Nomological machines exist for probabilistic laws, but they need to be constructed with care. A deceptively simple one is described by Cartwright on p. 157.

From a population of ten playing cards—four hearts, two diamonds, and four spades—a card is drawn at random. What is the conditional probability $p(D|R)$ that it is diamond, given that it is red? The machine that provides the answer requires what Hacking calls a 'chance set-up' (Ian Hacking, *The Logic of Statistical Inference*, Cambridge: Cambridge University Press, 1965, p. 152). Probability laws and probability values, whether objective or epistemic, do not make sense without chance set-ups such as dice, coins, shuffled decks, random sampling from populations, radioactive decay, etc. I shall take as the basic structure of a chance set-up, common to all these instances, a set of *possible futures* from which a *random selection* is made. The randomness entails that each future is equiprobable.

In the case of the playing cards it is assumed that each individual card has an equal chance of being drawn, so that the set of possible outcomes and the set of possible futures are the same. In general, however, this will not be so. The reason for distinguishing between possible outcomes and possible futures lies in cases where the outcomes are not equiprobable, as in tossing a biased coin. If 513 possible futures out of 1000 show the outcome heads, random selection of a single future out of the 1000 gives the probability of heads the value 0.513. The nomological machine consists of a set of possible futures, fixed proportionality subsets of which contain the same outcome, and random selection in the set gives each outcome its appropriate objective probability.

In the playing card example, the following formula gives the conditional probability of a drawn red card being a diamond:

$$p(D|R) = p(D \wedge R) / p(R) = {}^{2}\!/_{10} / {}^{6}\!/_{10} = {}^{1}\!/_{3}.$$

Now, Cartwright says, consider a more complicated set-up. First we perform two independent flips of a fair coin. If the results are *HH*, we draw a card from the six 'pointed' cards (diamonds and spades), otherwise from the non-pointed cards (that is, the hearts). If we now ask the value of $p(D|R)$ under the new set-up, the answer (p. 157) is ¼.

But is it? If the nomological machine is constructed properly, it may be seen that the correct value of $p(D|R)$ is not ¼ but ⅒. This is calculated as follows. The probability of a (red) diamond being drawn, $p(D \wedge R)$, is $p(HH)$ times the probability of a diamond being drawn from the six 'pointed' cards, i.e. $¼ \times ⅓ = 1/12$. The probability of a red card being drawn, $p(R)$, is the sum of the probability of a diamond being drawn when the coin falls *HH*, that is, $¼ \times ⅓ = 1/12$, and the probability of a heart being drawn when the coin falls *HT*, *TH*, or *TT*, that is, $¾ \times 1 = ¾$. So $p(R) = 1/12 + ¾ = 10/12$. As before, the value of $p(D|R)$ is $p(D \wedge R)/p(R)$, which in this case yields $1/12 / 10/12 = 1/10$. That the value is indeed ⅒ and not ¼ can be verified by repeated trials of tossing a coin and then drawing a card at random. About one in ten red cards selected in this way will be diamonds.

NM 6. Probabilities of joint correlated outcomes.

The probabilistic machines described by the chance set-ups in the previous example made essential reference to ordering in time (the coin tosses preceded the drawing of the cards, not vice versa), but were indifferent to considerations of space. NM 6 combines both space and time to yield predictions and explanations of distant probability correlations. Suppose two photons in the entangled Bell-EPR spin state $|H\rangle|V\rangle + |V\rangle|H\rangle$ are emitted from a source *S*, the left photon passing through an *HV* polarization analyser at *A* and the right photon through an analyser oriented at 30 degrees to the vertical at *B*. Considered separately, each photon has a 0.5 probability of passing *H* or *V*, + or − through its polarizer, but the joint probabilities $(V,+)$, $(V,-)$, $(H,+)$, $(H,-)$ are not each ¼ as they would be if the two measurement events were independent. Instead $p(V,+) = ½ \sin^2 30^\circ = ⅛$, $p(V,-) = ⅜$, $p(H,+) = ⅜$, $p(H,-) = ⅛$. A chance set-up which exploits both the temporal and the spatial features of this phenomenon and accounts for the distant correlations at *A* and *B* is the following.

Picture the sample space *S* as a set of distinct space-time futures which split and branch off along the simultaneity plane containing the events *A* and *B*. Imagine also that the proportion of members of *S* containing the joint outcome (*V*,+) is ⅛, the proportion of those containing (*V*,−) is ⅜, those containing (*H*,+) is ⅜, and those containing (*H*,−) is ⅛. Then random selection of a single space-time future out of the set *S* in this nomological machine (that is, random selection of the future which becomes 'actual') yields the observed EPR probabilities, and explains the correlations of *V* with + (25%), *V* with −(75%), *H* with + (75%) and *H* with − (25%). These correlations hold despite the fact that each individual outcome *H*,*V* and +,− has a probability of 0.5, and despite the fact that the individual results occur simultaneously at distant locations. What explains the correlations is the joint occurrence of pairs of distant measurement values on each space-time future of the nomological machine.

NM 7. Radioactive decay.

The role of chance in decay phenomena is not easy to pin down. What is it that gives each unstable atom or particle a constant probability of decaying within a given time interval, no matter whether the particle has remined undecayed for a microsecond or a year? A radium atom, or a free neutron, has the capacity to decay at any instant (one might say it was its 'nature' to decay). But what law ties that capacity to a precise half-life? A simple probabilistic machine makes the situation clear. Imagine time divided into arbitrarily short, but non-zero, equal intervals, say of the order of 10^{-24} seconds, with a branching node at the beginning of every interval. Then each unstable particle has a fixed probability of decaying within that interval, and the nomological machine which gives it that probability is a branching model with a constant proportion of decay and non-decay branches above every node. The probability of the particle decaying or not decaying within the next 10^{-24} seconds is given by those relative proportions. For example, free neutrons have a half-life of 1000 seconds, and the value of this half-life rests on the fact that one branch on every 2×10^{27} branches above each node is a decay-branch. The capacity of radium nuclei to decay is given by a different proportionality in each constant interval, and in general every non-stable particle has its own characteristic 'fingerprint', that is, the probabilistic space-time nomological machine which generates its half-life. In the case of particles the half-lives of which are not derivable from any physical theory, these fingerprints will be the only ontological truth-makers for their half-life values.

In conclusion I return to Cartwright's repudiation of the idea of science as the quest for a small number of abstract laws of great generality, in terms of which the entire physical world can be understood. The search for such basic laws, in the words of the high energy physicist Philip Allport, is the hallmark of 'great' science, and their discovery would provide 'the surest route to a thorough understanding of the workings of the universe' (P. Allport, 'Are the laws of physics "economical with the truth"?', *Synthese* 94, 1993, p. 248). For Cartwright, on the other hand, the world we live in is too complex, messy, and diverse to admit of being subsumed under a handful of 'basic' laws, such as the laws of elementary particle physics. Cartwright has no a priori argument that the search for such laws must necessarily fail (p. 10; see also Cartwright, 'Is natural science "natural" enough?', *Synthese* 94, 1993, p. 292). Instead she urges us to look at the evidence. What we see is not an all-embracing system but thousands of particular laws, each one valid within its domain, and valid only because hedged about with restrictions defining the nomological machine which creates it. These restrictions are the implicit *ceteris paribus* conditions with which Cartwright claims all laws of the exact sciences must be prefaced (p. 188). For science in general, including probabilistic laws which hold relative to the chance set-ups which generate them, the rule is '*ceteris paribus* laws all the way down' (p. 176). This phrase sums up the author's anti-fundamentalism.

When united with Cartwright's Aristotelian emphasis on scientific laws as based upon, and describing, nature's capacities, the connection between *law*, ceteris paribus *condition*, and *nomological machine* becomes evident. For Aristotle a capacity or potentiality (*dunamis*) may be of two kinds, rational or irrational. These are distinguished by the fact that a 'natural' potentiality (without reason) can result in one effect only, while a 'rational' or 'two-way' potentiality admits of one or the other of two contrary effects. Thus heat is a potentiality only for warming, while medicine is a potentiality for both sickness and health (*Metaphysics* 1046b6–7). But although in recent philosophical discussions *ceteris paribus* laws have generally been associated with the human sciences (see, for example, Jerry Fodor, *Psychosemantics*, Cambridge, MA: MIT Press, 1987, on belief/desire psychology), Cartwright makes it clear that if laws concern the exercise of capacities, then even a 'natural' potentiality exhibits its powers only within the confines of a nomological machine, and subject to the restrictions which govern its operation. But these restrictions comprise the very conditions to which the resulting law is subject. Bearing in mind the need to supplement capacity laws by laws of space-time structure, Cartwright's fourfold way relating (i) *law*, (ii) *capacity/space-time structure*, (iii) ceteris paribus *condition* and (iv) *nomological machine* is therefore complete.

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If You're an Egalitarian, How Come You're So Rich? by G. A. Cohen. Cambridge, MA: Harvard University Press, 2000. Pp. xii + 233. H/b £25.95, $39.00 P/b £12.50, $18.50

In his nine 1996 Gifford Lectures, collected here, G. A. Cohen discusses a variety of topics, ranging from the 'paradox of conviction' (why a person who knows that he believes *X because* he was brought up to believe *X* nevertheless