

Chapter 2

"Learning to 'control'"

Building blocks

According to the behaviorist tradition, the building blocks of all learning are associative in nature. When animals (including humans) are exposed to reinforcers; i.e., significant pleasant (aka "rewarding") or punishing (aka "aversive") stimuli - in combination with "neutral" ones such as a bell or a tone - links or connections are forged between hypothetical "nodes" in the central nervous system (or CNS) representing the elements in the learning environment. It is worthwhile grasping the principles underlying these processes because, intelligently interpreted, their capacity for understanding and predicting human behaviour, including psychopathology (behaviour needing treatment) and its "un-learning", is quite marvellously vast.

Scientific serendipity

Ivan Petrovich Pavlov (1849-1936) was a Russian physiologist awarded the Nobel Prize in 1904 for work on digestion. With the dogs in his laboratory already catheterised for saliva, Pavlov steered his attention towards the systematic investigation of a rather curious phenomenon: "anticipatory" secretion of saliva before presentation of food, particularly when, for any reason, food had not been presented.

The classical unit of learning

The basic procedure in Pavlovian or "classical" conditioning is as follows:

BASIC PROCEDURE IN PAVLOVIAN OR "CLASSICAL" CONDITIONING

"Trial"	Stimulus t1	Stimulus t2	Behaviour	Commentary
1	-	Food	Salivation	Food reliably elicits salivation. Because no learning is required, the food is referred to as an "unconditioned" stimulus or US and the salivation as an "unconditioned" response or UR.
2 + n as required	Bell	Food	Salivation	A neutral stimulus (one that is not particularly pleasant or unpleasant and which doesn't elicit a UR in its own right) such as a Tone or Bell is "paired" with the US by presenting it (immediately) prior to the US on several trials.
2 + n + 1	Bell	-	Salivation	After a sufficient number of trials, the previously neutral stimulus - now presented alone without the US - elicits behaviour that resembles or is identical to the UR. The change that has occurred is an instance of learning. The previously neutral stimulus is now referred to as a Conditioned Stimulus, or CS, and the elicited behaviour a Conditioned Response, or CR.

Essential principles of associative learning

Notes:

1. The US is known as "reinforcement", and is the driving force or "battery" behind learning (i.e., no reinforcement = no learning).
2. According to "stimulus substitution theory", the CS takes on the properties of the US¹⁴, in which case the CR should resemble the UR.
3. Since the UR to pleasant USs generally looks like "approach" behaviour, the CS will also look like "approach". The reverse is true for "aversive" reinforcers - the subject will "avoid" the CS.
4. The emotional states that accompany CRs may be understood broadly as (biologically established) "hope" and "fear" respectively¹⁵.
5. We can extrapolate out of the laboratory and to human beings: people will "hopefully approach" CSs previously paired with pleasant USs and "fearfully avoid" CSs paired with unpleasant reinforcers.
6. The number of trials needed for learning varies according to the "strength" of the US. In the case of "flavour aversion", where the US is an ingested toxin, only one trial may be necessary. Human beings learn quickly when the reinforcer is very powerful (or traumatic).
7. Learning is optimal when the CS precedes the US (i.e., forward conditioning) when it may continue with US onset (delay) or terminate prior to US onset (trace). In simultaneous conditioning, the CS and US occur at the same time. In backward conditioning, the US precedes the CS - intuitively a weaker case; after all, why would an animal learn about a stimulus that doesn't "predict" a significant event?¹⁶
8. The rate of learning may be affected by adjusting the inter-stimulus interval or ISI (time between CS and US which is optimal for a particular CS and US combination) and inter-trial interval (ITI).
9. The potential for explaining day-to-day human behaviour - particularly movement about the environment and emotional make-up (especially acquired disproportionate fear) - is virtually limitless, governed in scope only by the rich variations in the ways we encounter numerous motivationally significant stimuli in our routine affairs. As we all do this frequently, there is a great deal of reinforcement - and hence learning - happening all the time. The more one appreciates this, the more one can appreciate the "nurture" side of the "nature-nurture" debate (the other side being "inheritance").

¹⁴ possibly accounted for by a link forged during learning between theoretical "nodes" (neuronal representations) for the CS and US. It is important to remember that physiological accounts of learning are at an early stage of development, and that the actual identities of CSs and USs in the CNS - and the neuronal and synaptic changes associated with learning - are not in the least fully understood. It is a giant leap of speculation to contemplate the emergence of consciousness (let alone conscience) from CNS activity. There have been valiant attempts at driving relevant theory - see, for example, *Journey To The Centers Of The Mind* by Susan Adele Greenfield (1950-). Adequate theories of classical conditioning need to address known difficulties for "stimulus substitution theory" - including anomalous conditioned responding (i.e., CRs which are vague - or partial instead of entire URs - or which resemble UR opposites).

¹⁵ "Hope" and "fear" in non-human animals can only be imputed from observed behaviour - as non-humans lack the capacity for divulging verbal reports of subjective experience.

¹⁶ It is also possible to establish complex permutations of relationship (contingency) between the CS and the US in order to investigate both theoretical and physiological explanations for conditioning (usually involving neurons and synaptic plasticity).



"Learning About The Environment"
Vicar Lane, Leeds, West Yorkshire

The sheer scope of ways we can learn about the environment

We can appreciate this even more fully by considering empirically-established variations within the classical conditioning paradigm.

VARIATIONS WITHIN THE CLASSICAL CONDITIONING PARADIGM		
Effect	Description	Notes (for humans)
Latent Inhibition	Serial pre-exposure to the CS slows the subsequent rate of CR acquisition.	"I might get away with ignoring an unreliable warning."
US Pre-exposure	Exposure to the US prior to learning can retard the acquisition of a CR.	"I get what I want anyway."
Context Pre-exposure	Pre-exposure to the learning context can enhance fear conditioning.	"I thought this place was safe ... Get me out of here!"
Generalisation	A CR may be exhibited in some proportional way to stimuli which are not the CS but resemble it (possess overlapping characteristics).	"If it looks like a snake, and wiggles like a snake, it might be a snake."
Sensory Pre-conditioning	Two neutral stimuli are "paired" in several trials. One is then potentiated by pairing with a US, following which the other neutral stimulus elicits the CR even though it was never paired with the US.	"Don't tar me with the same brush!" and "I suspect a wolf in sheep's clothing."
Second Order Conditioning	Pairing of a potentiated CS with a neutral stimulus which then becomes potentiated in turn. The first CS has functioned as a reinforcer.	Fear spreads like wildfire ... (Is it like this for hope ... why not?)
Over-expectation	Reinforcement of compound CSs results in decrements in CRs which were acquired in prior conditioning with each CS alone (out of compound).	A given amount of predictive (US) power is shared amongst competing CSs.
Overshadowing	A stronger CR to a given CS presented alone than to the same CS presented in compound with a more salient one.	CSs can steal the predictive limelight from each other.
Blocking	Prior conditioning with a first CS prevents or inhibits acquisition of a CR to a second CS when both CSs are subsequently presented in compound.	"I already know all I need to know ... Why should I take notice of an impostor?"
Conditioned Inhibition	The inhibitory effect on a CR of a second CS when reinforcement is withheld during compound trials.	"Two's company ... Three's a crowd."
Super-conditioning	An enhanced CR to a given CS if it is presented in compound with a conditioned inhibitor (see above).	"Sorry, I took you for granted."
Extinction	Serial presentation of the CS without reinforcement results in diminution of the CR to pre-training levels.	"You've changed." (Why don't you love me like you used to?)
Extinction of Conditioned Inhibition	Pairings of the inhibitory CS with the US are required: presentation of the inhibitory CS alone does not produce Extinction of Conditioned Inhibition.	"A fly in the ointment must buy flowers."
Partial Reinforcement	Retardation of learning when the CS is not reliably paired with the US.	"You keep sending me mixed messages."
Recovery	Reappearance of a CR following its own Extinction in various circumstances, such as a novel context including presentation of a novel stimulus prior to the CS.	"I've forgiven, but I haven't forgotten." (There's always something there to remind me ...)



"I Might Get Away With Ignoring An Unreliable Warning"
Singing Sands, Ardnamurchan, Scotland

Three simple but important statements

All of these observations, variations and notes can be distilled into three simple statements:

1. Animals, including human beings, "endeavour" to discern relationships between environmental events - especially in order to "predict" the occurrence of those with adaptive significance.
2. It is possible to "un-learn" or somehow compensate for at least some of these by exposure to alternative stimulus contingencies.
3. In humans, there is a corresponding subjective "emotional life" which is some complex of "anticipatory hope" and "avoidant fear".

An additional learning mechanism involving "agency"?

Now, behaviorists recognise another type of learning which, conventionally, they distinguish from classical conditioning. It is ostensibly different from classical learning because a response (R) seems to be involved in association formation (with corresponding implications for the putative underlying physiological mechanisms). Theoretically, one can assume that "operant conditioning" (synonymous with "instrumental learning") can, in all instances, be explained in terms of classical (S-S) associations, even though it is difficult to generate a convincing case in some scenarios. The matter hasn't been resolved at the behavioural level - let alone in the central nervous system. So, what is operant conditioning? And why isn't it classical?

Description of operant conditioning (aka instrumental learning)

In the Skinner Box¹⁷ (or "operant conditioning chamber"), an animal (such as a rat or pigeon) is (usually) free to move about within its confines unencumbered; however, a variety of manipulations can be exercised by the (human) experimenter in order to investigate the set of principles that seem to underlie the subject animal's behaviour. The essential properties of the Skinner Box, aside from confinement, include its capacity for registering behaviour ("responses"), a means of delivering reinforcement (via a food box or a grid-floor through which electric current can be passed) and, optionally, administering "neutral" stimuli: "keylights" and sounds (bells, tones, buzzers). The experimenter determines a contingency between a response (usually a lever press) and the delivery of reinforcement. Whilst it may take some time for the lever to be pressed at all (since no motive already exists for the subject to do so), this eventually happens by chance (there being not a great deal else to do in a Skinner Box), and the recurrence of the same behaviour becomes more probable. In no time, our rat is pressing furiously. There appears to be (certainly as anticipated by the experimenter) a particular and necessary response (R) and the consequent occurrence of a reinforcer (S). The nature of the association formed or strengthened during operant conditioning is commonly considered to be R-S (implying a yet-to-be-discovered neural or synaptic change in or between "nodes" for a response on the one hand and the reinforcer on the other) and, thereby, distinguishable by category from classical conditioning (certainly as depicted in stimulus substitution theory where it is S-S). The associative nature of operant conditioning was formalised in an alternative way by Edward Lee Thorndike (1874-1949) in his "Law of Effect". Thorndike refers to reinforcers as "satisfiers" which strengthen associations between "situations" (in which the responses occur) and the responses themselves. This alternative interpretation may be expressed "S-R"¹⁸.

¹⁷ So named after B.F. (Burrhus Frederic) Skinner - the most archetypal, prolific and radical of behaviorists - to whom we have been introduced already. The Skinner Box was developed during his sojourn as a Masters / Doctoral student at Harvard in 1930-31.

¹⁸ As an historical aside, Thorndike's Ph.D. mentor was James McKeen Cattell - an erstwhile student of Wilhelm Wundt (to both of whom we were introduced in Chapter 1).



"Consequences": a weathered, melting iceberg near Greenland
from an original photograph by Mila Zinkova (Wikimedia Mbz1)

Definition of operant conditioning

Operant conditioning may be defined as a change in the rate of a conditioned (i.e., a learned) response depending on the schedule of reinforcement that accompanies it. It isn't difficult to think of numerous examples in everyday human life. If some action on our part seems to result in an event, or series of events, which in our subjective experience is pleasant; we are, on the whole, more likely to repeat or increase the rate of the behaviour that "produced" it. The reverse is also true: on the whole we will cease or reduce the frequency of behaviour that leads to circumstances that we find unpleasant. Exceptions may come to mind, particularly the realisation that folks (perhaps including ourselves) have at times seemed bent on the pursuit of behaviour that could only ever have brought misery to themselves and others. Of course, this is of enormous psychological interest - and we shall revisit it later when we consider (in)sanity.

Still one basic unit?

Why is it apposite to contemplate an "S-S" account of operant conditioning? It is a matter of combining alternative interpretations of conditioned behaviour with the principle of keeping things simple - which insists that we should not permit sophisticated explanations when basic ones will do: we mustn't complicate matters unduly. This tenet of necessary parsimony is known as "Ockham's Razor" after the English Franciscan friar William of Ockham (1288-1348, contemporary with Saint Thomas Aquinas and Saint Bonaventure). The rule holds that as few assumptions as possible should be adopted when explaining anything. For modern psychology, the notion was embodied in a canon attributed to the British zoologist, Conwy Lloyd Morgan (1852-1936):

In no case may we interpret an action as the outcome of the exercise of a higher mental faculty, if it can be interpreted as the exercise of one which stands lower in the psychological scale.

Lloyd Morgan's Canon and Thorndike's "Law of Effect" both contest the notion that animals (human or otherwise) discharge any spurious mental faculty whilst exhibiting ostensibly "intelligent" behaviour.

How operant responses might be classical

Referring back to our rat in the Skinner Box, couldn't its lever pressing be a CR arising out of the S-S pairing of the lever itself (CS) with food (the US)? Protagonists who defend the proposition that operant conditioning represents a mode of learning in its own right say that if operant responses were really all classical ones, they should only ever (according to stimulus substitution theory) resemble the unconditioned response to the reinforcer. In support of their case, they cite numerous examples of conditioned operant behaviour that don't resemble the UR remotely. Most of such operant theorists favour a Skinnerian (R-S or response-reinforcer) interpretation over a Thorndikeian (S-R or situation-response) one because the latter - requiring only the learning of a relationship between the context, or at least some element(s) of it, and the response (albeit strengthened by the occurrence of the reinforcer) - does not permit subjective anticipation or "agency" (no matter how "mind"-like this word seems).

A learning scenario: it could be you

The reader is invited to reflect, in the context of a hypothetical vignette, on what kind of learning - expressed in associative terms - may be proceeding during the development of preferences for, or aversions to, stimuli that once had no particular significance. Suppose in crossing the road outside your home, wearing your dashing new red coat, you are knocked over by a bespectacled driver who yells rather aggressively from a speeding green car that the incident was entirely your fault. Simultaneously, the church bell chimes the hour,

and a party of curious schoolchildren passes by on the other side of the road. Having hobbled home, you realise you had forgotten your own spectacles, and had been preoccupied all along with a family illness.

A variety of elementary learning mechanisms

Selected instances of associative learning about this incident mapped to each of the alternatives we have outlined are summarised below:

SELECTED INSTANCES OF ASSOCIATIVE LEARNING ABOUT AN ACCIDENT		
S-R (Thorndikeian)	R-S (Skinnerian)	S-S (Pavlovian)
You notice that you are hesitant crossing the road (R), but only outside your home (S). This is especially true if you are wearing your red coat, and when it's the afternoon - about the time when children leave school for home.	You notice that you hesitate more than usual when crossing the road anywhere (R). You have a vague (anxious) feeling that whenever you do this (approach the kerb to cross the road), something dangerous may be about to happen (S).	Abroad on holiday, you develop nausea (CR) when you see any green vehicle (CS) - even well away from public roads. It occurs to you that there isn't any rational reason for this: the nausea happens because of the accident (US).

Fear is a ubiquitous learning outcome

It is noticeable that all of these scenarios involve an unpleasant feeling (which we can approximate to fear), and the very way the circumstances in each case are expressed seems to reflect the various assumptions made about the learning experience; moreover, it is very difficult to tease out a Skinnerian account from a Thorndikeian one.

The adaptive significance of learning

Before leaving behaviorist accounts of learning, it is appropriate to pause briefly to reflect on their adaptive significance, and how conditioning might generate rogue emotional states. We can imagine readily how, in natural selection, developing approach and avoidance behaviour in relation to certain conditioned stimuli might improve an organism's chances of obtaining food or avoiding dangerous predators. This is to say, it is not difficult to see how evolution might have generated associative learning for survival purposes. This is not to go so far as to say that associative learning is, in fact, the outcome of an evolutionary process except in so far as all phenotypes are. Assuming, nevertheless, that there is a strong case, why would it generate emotional complexes common in humans that are, from the psychotherapist's side of the coffee table, irrational and crippling?

Summary of classical and operant conditioning

Further reflections on these problems feature in Chapter 9. For now, the main points (with ancillary notes) can be summarised as follows:

1. Classical conditioning looks like an adaptive asset in which organisms "endeavour" (within a reliable inter- and intra-species system incorporating a tendency to persist) to "predict" (anticipate in the future) the occurrence of biologically significant stimuli.
2. Operant conditioning refers to a change in the likelihood of behaviour depending on its outcome, appears to be designed to "control" the occurrence of reinforcers and is, at least in some cases, open to classical interpretation (S-S) as well as S-R and R-S.
3. Classical and operant conditioning generate conditioned emotional states; we may say "anticipatory hope" and "avoidant fear", a complex combination of each present in any individual's affective profile.

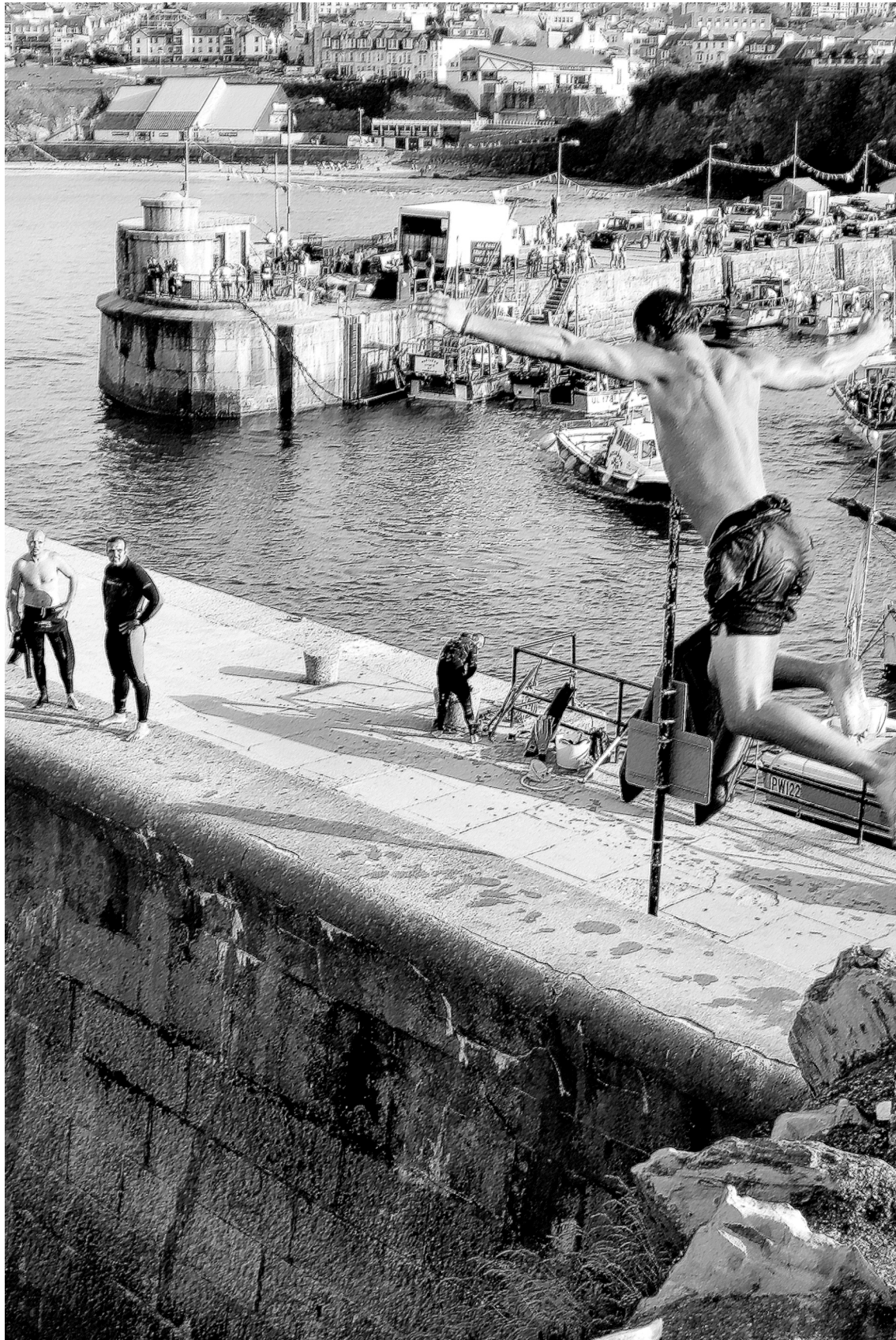


"No 'I Deer' How The Mind Works"

4. Via language, humans can express their subjective experience of conditioned emotional responses (CERs), but non-human animals cannot.
5. Using appropriate stimulus (and sometimes response) contingencies, conditioned behaviour can be "un-learned", "overwritten" or otherwise compensated for. (This is the basis for "behavioral" psychotherapy.)
6. Accounts of associative learning that have taken a century to build (and here we have outlined only the very elementary aspects) have adhered scrupulously to principles of parsimony in developing theory; nevertheless, it is still not known whether there is a single associative mechanism for classical and operant conditioning, or whether they rely on two or more fundamentally different processes.
7. The physiological plasticity that is assumed to underpin the behavioural changes seen in associative learning has been investigated in simple organisms¹⁹, and some progress has been achieved in detecting matched behaviour-neurobiological alterations - particularly at synapses in the nervous system. To say that there is anything like a complete or even provisionally comprehensive account of the neural substrates of learning would be a gross overstatement.
8. Colloquially, most humans are happy with concepts such as "consciousness", "conscience" and "choice", and can describe these on both conceptual (everybody's got one) and subjective (this is what mine looks like) levels; nevertheless, we have come to expect radical behaviorists to be reluctant to acknowledge such phenomena as "real".
9. For B.F. Skinner, a "scientific determinist" as well as a radical behaviorist, there is no such thing as "free will": the movement of an organism about its environment can be accounted for fully and causally in associative terms; i.e., behaviour obeys scientific laws.
10. Whether Skinner is correct or not, any organism's subjectively experienced capacity for "controlling" its environment that arises out of conditioning processes may be illusory anyway²⁰, and this applies to humans. Aberrant CERs, such as disproportionate fear, are a specific case - not just because they are irrational - but because they have a counter-adaptive effect on functioning. Such modern heresy constitutes no argument against "consciousness", "conscience" and "choice" - which may rely on discriminable (or other) faculties.
11. If scientific knowledge about the neural substrates of learning is preliminary at best, it follows that theoretical approaches to any putative physiological basis for more elusive mental faculties such as "consciousness", "conscience" and "choice" are tentative at best.
12. Finally, the existence of the same mechanisms and processes for learning within a species doesn't necessarily mean that all members of that species will behave the same way in the same circumstances. There are individual differences in human behaviour that seem to hinge on resilience; in fact, we might justifiably say that modern psychology is pre-occupied with "toughness" of one kind or another. Which of these differences are genetic or otherwise "inherent", and which are "acquired" or otherwise amenable to modification - whether through psychotherapy or some less expensive route? Let's face it: "It's easy when you know how" and "The best things in life are free".

¹⁹ A common example is a laboratory preparation of the sea snail *Aplysia Californica*.

²⁰ Chapter 9 features creative and thorough expansion of this and related propositions.



"Extravert"
Newquay Harbour, Cornwall