1 Ivan Pavlov, Conditioned Reflexes and Experimental Neuroses

Pavlov was in his 50s when he and his young collaborators began to study conditioned reflexes in dogs. Chapter 1 starts with an account of how their research began and describes some of the major findings that followed from the decades of intense work that continued right up until Pavlov's death at the age of 86. Many of the topics that he was the first to study later became the focus of research both inside and outside of Russia. Subsequent chapters in this book describe the development of research in English-speaking countries, predominantly the USA, on many of the aspects of learning by animals that were first examined in Pavlov's experiments on conditioning.

The latter part of the present chapter focuses on a topic for which Pavlov is less well known, *experimental neurosis*. Among those actively inspired by his ideas on neuroses were two US-based researchers, Horsley Gantt and Howard Liddell, who became the staunchest proponents of Pavlov's theories in the English-speaking world. An account of their work and that of those that followed in promoting the application of Pavlov's ideas to the study of neurosis is followed by an important critique of Pavlov's theories of how the brain works by the Polish scientist, Jerzy Konorski.

Problems with Digestion Research

The story of how Pavlov began to study conditioning is an unusual one. To start with, Pavlov's reputation for research on a very different topic was at its peak when he made the major shift from mainstream experimental physiology to study what was essentially a psychological problem.

Over the many years from when Pavlov worked as a lone scientist – usually working in someone else's laboratory – till when he headed a large team of research workers in his own well-equipped laboratory, he developed at least two important skills. One was surgical: Pavlov was one of the most accomplished physiologists of his era in terms of his ability to isolate surgically different parts of a dog's digestive system and insert fistulae – tubes – into various levels of this system. Importantly, he was able to carry out such operations in such a way as to achieve – at least on most occasions – his aim that the dog would survive and live in good health for many more years. During this time, such a dog could be the subject of a series of chronic experiments on how its digestive system worked.[1]

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A very different skill was that of training, managing, and inspiring the 10–15 poorly-prepared medical students who arrived each year to work in his laboratory. What they wanted was to carry out enough research for a thesis that would earn them a doctoral degree. The content of these theses was limited and more comparable to the kind of report that a final year undergraduate in a Western university might submit than to a Ph.D. thesis. A student in Pavlov's laboratory would normally be allocated a single dog that may have already undergone surgery. Alternatively, a student would be incorporated within a team that might include Pavlov or a skilled research assistant to carry out some surgical procedure on a new dog. What Pavlov wanted from a student was data that would contribute to Pavlov's focused research strategy.[2]

From his earliest research on the heart, Pavlov had consistently embraced a theoretical position known as *nervism*. As applied to the digestive system, this was the belief that every stage in the digestion of food is coordinated by the central nervous system. Experimental support for this view consisted in demonstrating, for example, that an isolated segment of a dog's stomach – the *Pavlovian pouch* – would secrete gastric juices in response to food that entered the mouth, but fell out through a fistula in the esophagus – but only if the nerves connecting the brain to the pouch were intact. Such demonstrations were based in many cases on combining results from several student projects, and many were reported in Pavlov's first book, *Lectures on the Digestive System*, which was published in Russian in 1897. Subsequent translations into German, then French and English, gave Pavlov an international reputation and eventually led to him being awarded the Nobel Prize in 1904. This was the first to be awarded in physiology, and Pavlov was the first Russian to be honored in this way.[3]

Well before his Nobel Prize and soon after publication of his 1897 *Lectures*, doubts began to emerge concerning the claims that Pavlov had made in his book. One source was a discovery concerning the activity of the pancreas by one of his students, a result that was reluctantly confirmed by Pavlov. This study revealed that claims made about the pancreas contained in his 1897 book were incorrect. The need to retract previous claims in the light of subsequent research is common enough in any kind of scientific program. What was far more disturbing and led to one of the most violent outbursts of Pavlov's renowned fury was a critical analysis of the data reported in the *Lectures* of 1897 by a former student. Popel'skii was older and more independent-minded than most of the other students when he began to carry out experiments under Pavlov's direction. In Pavlov's *Lectures,* it was not readily apparent that the results reported in this book were mainly obtained from just two dogs. Popel'skii re-examined the theses on which Pavlov had based his claims about the pancreas and concluded that the reported data were selected to support the claims Pavlov wished to make and that another, more objective reading of these data would support conclusions opposite to those favored by Pavlov. Popel'skii even had the temerity to publish articles containing his criticisms of Pavlov in foreign language journals.[4]

The most important development to undermine Pavlov's claims regarding the digestive system came from a discovery made by two British physiologists that was prompted by a study from Pavlov's laboratory and that used procedures he had pioneered. With his long commitment to nervism, Pavlov had always rejected the idea that hormones played any role in the control of digestive processes. In 1902, Bayliss and Starling reported their discovery of secretin, a hormone that influences the action of the pancreas. Pavlov immediately set a student to attempt a replication of the critical experiment reported by Bayliss and Starling. As Pavlov was forced to acknowledge, the replication indicated that Bayliss and Starling's claim was correct.[5]

Psychic Reflexes

In experiments in which gastric juice was obtained by giving a dog meat powder or some other food, Pavlov and his students consistently observed that simply waving the food in front of the animal – 'teasing' – would start the juice to flow. By 1892, Pavlov had begun to refer to such effects as psychic reflexes. He explained them as being the product of mental processes such as 'choosing' or 'deciding.' In 1896, a similar phenomenon was found by Vulf'son, one of the first students assigned by Pavlov to study the salivary glands. Vulf'son first established that whether or not one of his four dogs produced mucus-rich or thin, watery saliva depended on whether plain meat or something noxious – including meat covered in mustard – was placed in its mouth. Most importantly, when teased with meat, the dog's psychic reflex produced mucus saliva but, when teased with something that the dog had learned was noxious, watery saliva was collected.

Pavlov became increasingly interested in psychic reflexes. Lacking any background in psychology, in 1900, he took the unusual step of taking on a student, Snarskii, who had received some training in another laboratory, that of Vladimir Bekhterev. A few years later, Bekhterev also began to study conditioning but used a very different approach to Pavlov's (see Chapter 4). For this and other reasons, Bekhterev became Pavlov's greatest rival.[6] While in Bekhterev's lab, Snarskii had also gained some expertise in psychology. After arriving in Pavlov's lab, Snarskii first extended Vulf'son's study by using a black-tinted solution of mild acid that, when injected into a dog's mouth, produced copious amounts of watery saliva. Once a dog had experienced this treatment several times, it began to salivate as soon as it was shown the bottle containing the acid.

A key finding followed. When Snarskii repeatedly showed the dog the bottle without injecting its contents into the dog's mouth, he obtained a decreasing amount of saliva. This could be seen as the first ever extinction experiment. It showed that this psychic reflex was *conditional* on maintaining a pairing between a dog seeing the bottle and then experiencing the acid within its mouth.

Snarskii was critical of Pavlov's use of the term 'psychic' and Pavlov's generally anthropomorphic approach to his dogs' personalities and presumed mental processes.

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Snarskii preferred to describe his dogs as forming 'associations' between 'representations' of events, a process in which "the consciousness of the dog plays no important role." Bekhterev was a member of Snarskii's thesis committee, as well as Pavlov; at its meeting Bekhterev allegedly told Snarskii: "Your duty and mine is to teach physiologists psychology!"[7]

In 1901, Pavlov found another student to work on this topic. Tolochinov, llke Snarksii, had previously worked in Bekhterev's laboratory, but also had considerable clinical experience working with patients suffering from various mental disorders. He was already in his 40s when he started to work in Pavlov's laboratory. Thus, he was far older and, more importantly, like Snarskii, Tolochinov had much greater knowledge of research outside of Pavlov's domain than most other students. In particular, he knew about studies of human 'reflexes at a distance' that had demonstrated that a knee jerk or an eye-blink could occur in anticipation of the stimulus normally needed to elicit such responses.

Starting in February, 1902 Tolochinov systematically examined the extinction effect that Snarskii had reported. Furthermore, he discovered what many decades later was re-discovered and labelled *reinstatement*. After repeated 'teasing' by, for example, showing, but not giving, his dog some meat so that salivation had virtually ceased, letting the dog eat the meat on a single occasion would then restore the effectiveness of the sight of the meat to elicit saliva. Discussion of these results led Pavlov to coin the term *conditional reflex.* The first public use of the term was in a presentation by Tolochinov at a meeting in Helsinki in June 1902.[8]

In the meantime, most experiments undertaken within Pavlov's laboratory continued to focus on the physiology of the digestive system. However, the increasing importance that Pavlov gave to the conditional reflex is shown by two events. First, this was the topic he chose for his invited lecture to the meeting of the International Congress of Medicine that took place in Madrid in 1903. Second, in the same year, he pulled one of his most promising students, Babkin, from studying the pancreas and directed him to study conditional reflexes instead. The transition to the eventual situation whereby all the laboratory's resources were devoted to the study of conditioning was not complete until 1907. By that time Pavlov had completely adopted the 'objective' language that Snarskii had argued for and instituted for some years a system whereby students were fined for using the mentalist vocabulary that Pavlov himself had happily used only a few years earlier. Indeed, from 1906 onwards, Pavlov promoted the story that it was he, and not Snarskii, who had first wanted to exclude the everyday language of human mental processes from the quest to understand conditional reflexes.[9]

At some level, Pavlov must have recognized during this transition period that he did not have the skills to remain at the new cutting edge of research on the digestive system. On the other hand, he became more confident in the belief that the study of conditioning would provide a tool for examining "the seeming chaos of relations" with which the behavior of an animal comes to adapt to its world and for identifying general laws that govern changes in behavior. And even more important, it would lead to an understanding of how the brain worked (Figure 1.1).

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Figure 1.1 Ivan Pavlov in 1890. Public domain.

Discovering the Properties of Conditioned Reflexes

Prior to 1890, Pavlov had only part-time, short-term academic appointments that failed to earn him enough to keep his family out of poverty. He also had limited access to lab facilities. His situation dramatically improved in 1890 so that until the outbreak of World War I in 1914, the resources at Pavlov's disposal were considerable; see Figure 1.2.

In the late 1880s, a wealthy aristocrat related to the Czar wanted to establish an institute for the study of infectious diseases – one concentrating on rabies – that would rival the world-renowned Pasteur Institute in Paris. Finding the considerable amount of money to fund what would become the largest research institute in Russia proved to be easier than finding top scientists, preferably experts in disease, to head its various laboratories. Partly by being on the right committee at the right time and having important contacts, Pavlov was appointed the Director of its Laboratory of Experimental Physiology when the Imperial Institute for Experimental Medicine opened in 1890. This provided him with as much space and with facilities as good as any physiological laboratory in the world at that time.[10] In addition, the income to the Laboratory was sufficient to provide Pavlov with a good salary for the first time in his life and, in most years, to pay the salaries of two full-time research assistants and those of two attendants who cared for the dogs and often assisted with experiments.

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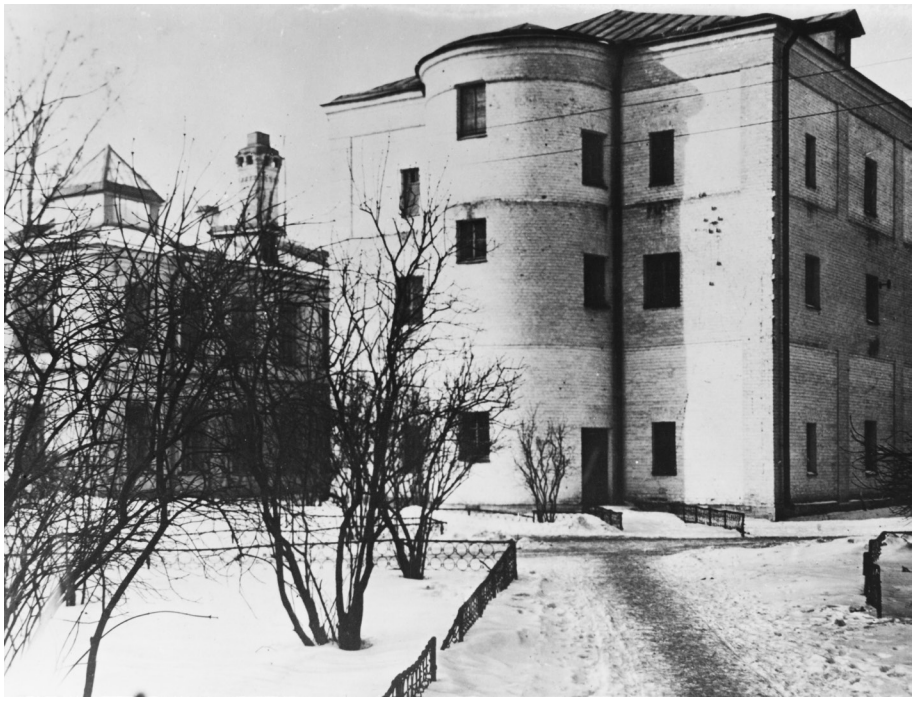

Figure 1.2 The special laboratory built for Pavlov in the Institute of Experimental Medicine in St. Petersburg.
Image credit: Topical Press Agency / Stringer / Hulton Archive / Getty Images.

Just as important a resource was mentioned earlier. His appointment from 1890 onwards at the Military Medical Academy led to a steady flow of medical students to work in his laboratory. Their aim was to obtain a doctoral degree that would advance their official position in Russian society and for the majority improve their chances for a favorable appointment within the Russian army. In a paper on conditioning that Pavlov wrote just before the outbreak of World War I, he acknowledged the contributions of over 100 "collaborators."[11]

Starting in 1898, an added boost to the budget came from the sale of gastric juice obtained from dogs whose sole purpose was commercial rather than scientific. Gastric juice from these dogs was supplied both for research purposes to other laboratories in Russia and elsewhere in Europe and to meet the considerable local demand for the juice as an aid to digestion. This enterprise was so successful that in 1904, it increased by over 65% the income to a laboratory that was already far more richly supported than any other Russian physiology laboratory.[12]

No one else in the world had anything like these resources for studying how animals learn. Even when, as described in Chapter 2, Clark Hull was set up in the Institute for Human Relations at Yale University, the laboratories in which his co-workers and students worked and the resources at their disposal in the 1930s hardly compared to Pavlov's laboratory prior to World War I; see Figure 1.2.

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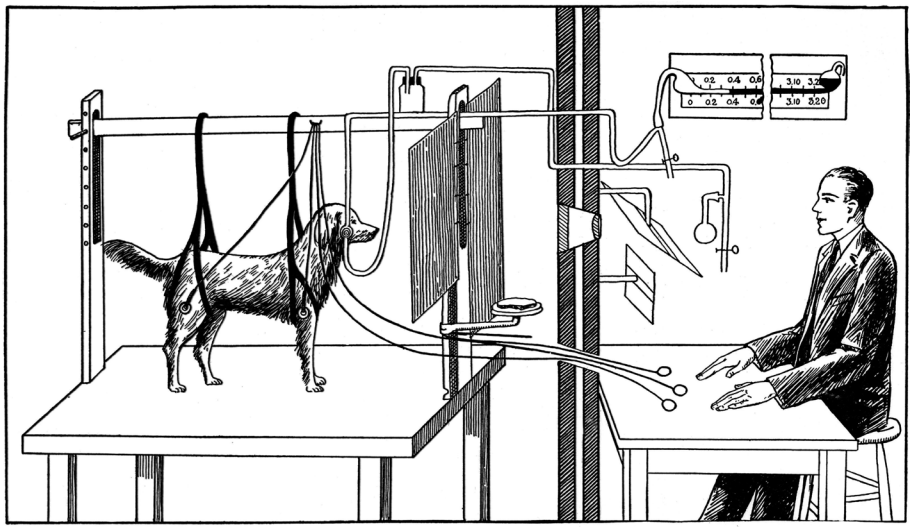

Figure 1.3 Sketch from 1928 of the standard arrangement used for salivary conditioning experiments in Pavlov's lab.
From Pavlov (1928). Reproduced with permission from Alamy.

Pavlov's research barely survived during the war and, following the Bolshevik revolution of 1917, his laboratory had to shut down for two years.[13] During 1918 and 1919, Pavlov and his family had barely enough food, let alone enough extra to maintain a colony of dogs; several had to be sacrificed.[14] Unexpectedly for someone who had been critical of the communist movement in Russia, Pavlov's fortunes improved even before the nation's political and economic situation had begun to stabilize. Lenin wanted to show that the new communist government supported science, and Pavlov was Russia's only Nobel Laureate. In 1921, Lenin signed a decree authorizing a committee to "create as soon as possible the most favorable conditions for safeguarding the scientific work of Academician Pavlov and his collaborators."[15] This resulted in Pavlov, now 72 years old, enjoying ample funding for the rest of his life.

The method used in most of Pavlov's experiments on conditioning was based on his previous studies of the digestive system. Surgery was first performed to insert a permanent fistula in a dog's cheek through which saliva could drain out through a tube. Then the dog was trained to stand on a bench where it was lightly restrained by a harness. Once a dog had completed such initial training, it served in experiment after experiment. Most of Pavlov's varied mongrels lived for many years; see Figure 1.3.

Considerable effort went into ensuring that a dog was unable to detect movements, even "blinking of the eye lids," or sounds made by the experimenter. Pavlov believed that it was extremely important to eliminate extraneous stimuli that might distract a dog and compete with the experimental stimuli. "In order to exclude this undue influence on the part of the experimenter as far as possible, he had to be stationed outside the room in which the dog was placed. … The environment of the

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animal even when shut up by itself in a room, is perpetually changing. Footfalls of a passer-by, chance conversations in neighboring rooms, slamming of a door or vibration from a passing van, street cries, even shadows cast through the windows into a room, any of these casual uncontrolled stimuli falling upon the receptors of the dog set up a disturbance in the cerebral hemispheres and vitiate experiments." Known as the 'Tower of Silence,' the Institute building was surrounded by isolating trenches; the research rooms were well insulated from each other and partitioned by sound-proof material.[16] "By means of these arrangements, it was possible to get something of that stability of environmental conditions so essential to the carrying out of a successful experiment," Pavlov reported in the first lecture of his 1927 book.[17] Few subsequent researchers have gone to such lengths when studying conditioning.

A summary of Pavlov's main achievements is most appropriately given in terms of the vocabulary that he invented. It has survived ever since in the context of what will be called *Pavlovian conditioning* in this book, as opposed to the equivalent label, *classical conditioning*, that is also commonly used. To start with an event used in a large number of Pavlov's experiments, presenting a dog with a small amount of meat served as the *Unconditioned Stimulus* (UCS or US), an action that elicited the preexisting reflexive response of producing saliva as the *Unconditioned Response* (UCR or UR). Pavlov used a variety of neutral stimuli in his lab; 'neutral' in the sense that they did not at first elicit any salivation. A favorite was a metronome whose ticking for a preset time was set at a particular frequency. When this sound was made just before a dog was given food, the ticking of the metronome was said to serve as a *Conditioned Stimulus* (CS). After many such pairings, the CS would typically come to elicit salivation as the *Conditioned Response* (CR).

Some of the first conditioning experiments performed in Pavlov's lab used the procedure that came to be known as *extinction*. Once a CR had been established to a CS by pairing the latter with the UCS, the CS was presented repeatedly in the absence of the UCS with the result that the CR occurred with decreasing frequency. This led Pavlov to view the occurrence of the CR as 'conditional' upon its continued pairing with the UCS and hence introduced the term (in Russian), 'conditional reflexes.' When his lectures were translated into English, 'conditional' became 'conditioned'; hence the term, *conditioning*; see Figure 1.4.

Pairing of two events can be arranged in a variety of ways. They can, for example, occur at exactly the same time, the *simultaneous* condition shown in Figure 1.5. Despite the historic claims by associationist philosophers that this was the optimal arrangement for the formation of associations between two events, Pavlov did not find this arrangement effective for establishing a conditioned reflex. Instead, he found that the most effective form of pairing was the *delayed* arrangement; here the onset of the CS precedes that of the UCS and they terminate together. Also extensively used in Pavlov's lab was the *trace* arrangement, whereby the CS is presented for a short time, followed by an empty interval before the UCS arrives. The term 'trace' reflects the idea that a memory trace of the CS becomes connected to the UCS. The final arrangement shown in Figure 1.5 is termed *backward* conditioning, in that the CS follows the

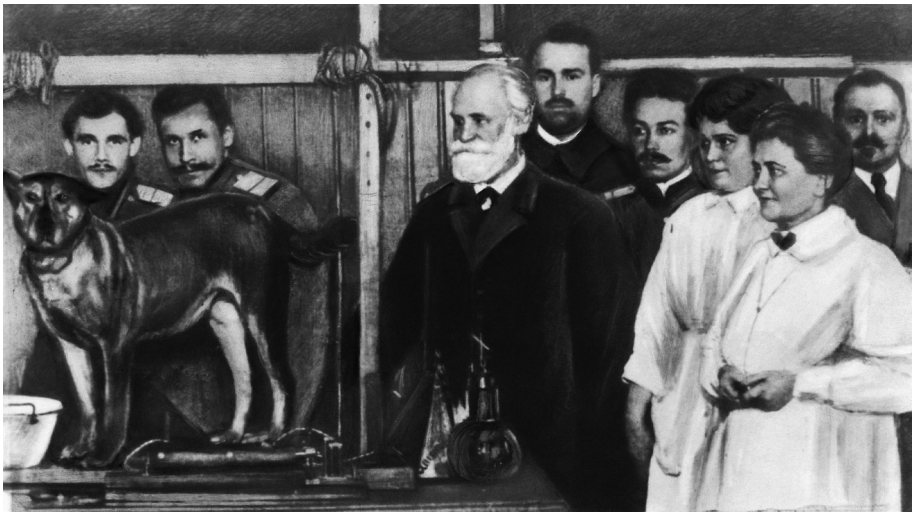

Figure 1.4 Pavlov, plus two students, three co-workers, two assistants and a dog.
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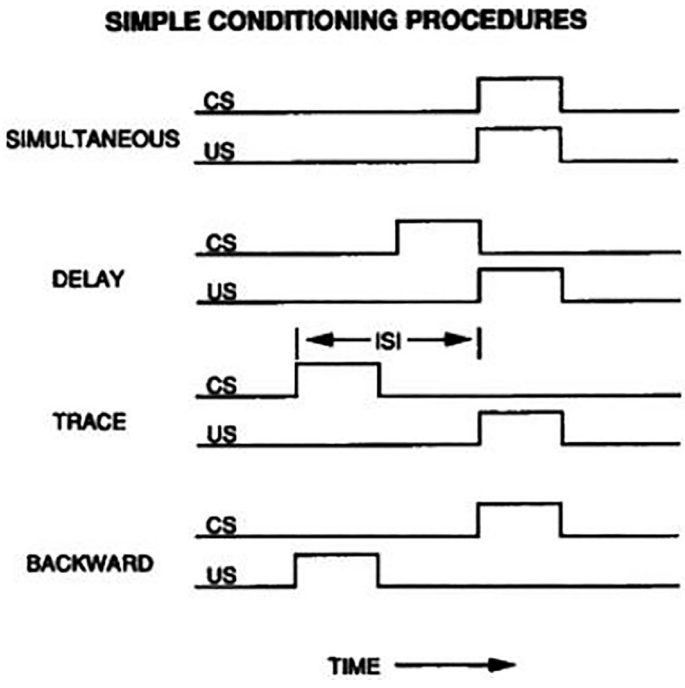

Figure 1.5 Different ways to present the conditioned stimulus (CS) and unconditioned stimulus (US) in time. This diagram from a book published nearly 60 years after Pavlov's death shows how the terminology that he introduced lives on.
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UCS. Decades later, many attempts were made to show that Pavlov's conclusion that no conditioning occurred under this arrangement was wrong.

Once again following the approach in his physiological studies, usually only a single dog, but sometimes two, were used in an experiment. When Pavlov was not totally convinced by a set of results, a new student was set the task of replicating the previous experiment. And almost all of the phenomena that Pavlov discovered by these means have been replicated ever since.

In the very early studies of extinction it was noted that, when a dog was returned to the lab after a delay of a few days, the presentation of a CS would once again evoke the CR; this effect was called *spontaneous recovery*. The CR could also recur after it had been extinguished if some unexpected stimulus occurred – for example, Pavlov walking into the room; this was called *disinhibition*. Commenting on such effects, Pavlov wrote: "By ruling out one interpretation after another we arrived at the conclusion that extinction must be regarded as a special form of inhibition."[18]

The term 'inhibition' was also used in a label applied to a form of discrimination training that was extensively studied in Pavlov's lab and that was very important for theoretical developments many decades later (see Chapter 9). One stimulus, A, was followed by food when it was presented on its own, A+, but not when a second stimulus, B, was present at the same time. A+ vs. AB– was termed *conditioned inhibition* training and B termed a *conditioned inhibitor*. To check that B had acquired inhibitory properties, a *summation test* was used; this asked whether adding B to a second excitor, C, to form a simultaneous compound stimulus, BC, would result in fewer responses than when C was presented alone.

A simpler form of discrimination learning, A+ vs. B–, was said to involve *differential inhibition.* This procedure was used in a large number of experiments to examine the dogs' sensory abilities, an area of research that was later called *animal psychophysics*. For example, *easy-to-hard* training could start with a large difference in frequency of the clicks from a metronome that served as the source of stimuli; once the dog was vigorously salivating to A+ but very little to B–, then the difference between the two frequencies was progressively reduced session after session until the dog failed to respond differentially to the two stimuli. Experiments using lights of different wavelength failed to detect any ability of dogs to see colors.

Other experiments studied *stimulus generalization*. "For instance, if a tone of 1,000 d.v. is established as a conditioned stimulus, many other tones spontaneously acquire similar properties, such properties diminishing proportionally to the intervals of these tones from the one of 1,000 d.v. Similarly, if a tactile stimulation of a definite circumscribed area of skin is made into a conditioned stimulus, tactile stimulation of other skin areas will also elicit some conditioned reaction, the effect diminishing with increasing distance of these areas from the one for which the conditioned reflex was originally established."[19]

Another important effect first identified in Pavlov's lab and then extensively studied in the 1970s (see Chapter 9) was *second-order conditioning*. Such experiments start with first order conditioning of a previously neutral stimulus, say A, and then a second neutral stimulus, say B, is paired with A; thus, B– > A, in the absence of the

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original UCS. If this results in B now evoking a CR, second-order conditioning is said to have taken place. Neither Pavlov nor anyone since has been successful in demonstrating third-order conditioning.

Pavlov's Theories of Brain Processes Underlying Conditioning

Many of the phenomena summarized in the previous section and the experiments in Pavlov's lab that studied them were described in American textbooks of psychology by the late 1930s. However, there was at best limited mention of a long series of experiments that Pavlov's students and co-workers carried out in the early 1920s. These centered around Pavlov's theory of the processes in the brain that gave rise to conditioning. For him, as a physiologist, the main point of studying conditioning was to understand the "workings of the higher nervous system." He was dismissive of approaches that relied on cutting out parts of the cerebral cortex. "Imagine that we have to penetrate into the activity of an incomparably simpler machine fashioned by human hands, and that for this purpose, not knowing its different parts, instead of carefully dismantling the machine we take a saw and cut away one or another fraction of it, hoping to obtain an exact knowledge of its mechanical working!"[20] This argument was, however, followed by lectures that reported conditioning experiments on dogs that had had part of their cortex removed.

No neuroscientist today would quarrel with Pavlov's basic idea of how sensory inputs are processed by 'analyzers' and represented in cortical 'centers' or with the idea that a 'UCS center' sends out signals to such organs as the salivary glands. However, what seems strange are Pavlov's ideas on what happens across the cerebral cortex. He proposed that conditioned responding depends on conflicting waves of excitation and inhibition moving out from cortical centers and then receding. To measure the progress of such waves, a large number of experiments in Pavlov's lab varied the interval from, say 1 to 15 minutes, between the presentation of stimuli that were reinforced, CS+s, and other others that were non-reinforced, CS-s.

Few Western researchers have ever followed up on this kind of experiment. Partly, one can suppose, this is because Pavlov's ideas on events in the brain had been outmoded since early in the twentieth century. He seems to have known about Cajal's demonstration that the nervous system was made up of discrete neurons that made contact with each other via synapses and he quoted Sherrington who had embraced this idea. Yet Pavlov clung throughout his life to a view current in 1900 whereby "nerve cells were joined in a kind of three-dimensional netting along which nervous messages could flow roughly spherically …. it is as though, in 1900 or thereabouts, he stopped listening to what was going on elsewhere. After all, his own experiments were enough to keep him busy."[21]

At another level of theory Pavlov's claims of what happens during simple excitatory conditioning remained very clear. A connection is established between the CS center and the US center, such that when the CS center is stimulated excitation passes

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to the UCS center and this tends to evoke the UCR. Thus, a process of *stimulus substitution* takes place, whereby the CS now elicits the same response as elicited by the UCS, a *conditioned reflex* is formed. What was unclear – and Pavlov continued to change his mind on the topic until he died – was the relationship between the various types of inhibition he described.

Experimental Neuroses

Pavlov and his collaborators treated their dogs very well. They had individual names and were treated almost as pets. Most lived in the institute kennels for several years and served in many experiments. A calm, well-socialized dog provided good data. Consequently, when a dog started to behave in an atypical way, this stood out.

An early example was in 1911, when one of the earliest female students to work in his lab, Maria Erofeeva, tested the effects of delivering a brief electric shock as a signal for the delivery of food. Some dogs showed what became known as *counter-conditioning* in that their initial response to the shock was replaced by salivation. However, two dogs subjected to such training subsequently showed prolonged disturbed behavior.[22]

Ten years later such behavior was displayed by a dog serving in a very different kind of experiment. Nadezhda Shenger-Krestnovikova used discrimination training in which the projection of a circle onto a screen was followed by food delivery, while presentation of an ellipse was not. Once the dog was consistently salivating to the circle, but not to the ellipse, the ellipse was gradually made more circle-like up to the point – the ratio of the axes reached 9:8 – when the dog no longer responded differentially to the two stimuli. Pavlov reported that "the dog which formerly stood quietly on his bench now was constantly struggling and howling."[23] Influenced by Freud's case histories – despite firmly rejecting the latter's theories – Pavlov labeled this change "experimental neurosis."[24]

Pavlov's belief that he could provide a rigorous scientific basis for the study of abnormal behavior, including human neuroses and psychoses, was further strengthened by a natural calamity that hit St. Petersburg in 1924. A huge storm led to flooding of the institute kennels. The dogs were saved by making them swim out in small groups. They were then housed on the first floor of the laboratory until the flood had receded. When normal experimental routines were resumed, some of the dogs showed "disturbance of their conditioned reflexes" for a considerable time.[25]

For the final decade of his life Pavlov became increasingly concerned with such topics. He envisaged a normal dog as one for which the processes of excitation and inhibition were balanced within its brain. Neurosis results from a 'collision' between these processes. By no means all dogs showed disturbed behavior after serving in an experiment where a shock signaled food or in one that required discrimination between a circle and a circle-like ellipse. Similarly, only a few dogs were traumatized by the flood. This contrasted with the consistency with which dogs responded in more standard experiments. Consequently, Pavlov's long interest in the different

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personalities of his dogs developed into his theory of 'types.' Thus, for example, referring to the effect of the flood, he wrote that "dogs with a weak nervous system, having a predominant inhibitory process … (that) … reproduces the etiology of a special traumatic neurosis."[26]

His developing interest in mental illness led Pavlov to visit psychiatric wards several times a week when he was in his 80s. His analysis of two cases of schizophrenia, a girl in her early 20s and a 60-year-old man, in terms of "isolated inhibition of the motor region of the cerebral cortex" seems now at best quaint.[27] He commented on a case of "hysterical psychosis" in a woman who, after her husband deserted her, later taking away their child, "sank into dotage": "a closer examination of the patient shows that everything seems to be accounted for exclusively by the absence of the analytical inhibition which always accompanies our behavior, our movements, words and thoughts, and which distinguishes the adult from the child."[28] Not much empathy on display.

It is something of a puzzle that Pavlov does not seem to have been concerned with how his analyses of various kinds of human psychopathology might lead to effective therapies. Even for a dog showing symptoms of experimental psychosis, the only treatments considered were either to give it a 'bromide,' a sedative popular in that era, or sleep and prolonged rest.[29]

The development of therapies based on conditioning theories were, however, developed in the English-speaking world. Pavlov's interest in psychopathology had attracted the attention of the most influential American psychiatrist of his generation, Adolf Meyer. An earlier colleague of Meyer's was John Watson, whose *Behaviorism* of 1924 had promoted the idea that Pavlov's conditioned reflex theory would provide the cornerstone for a truly scientific psychology. Meyer visited Pavlov in 1925 and later a research-only position in his psychiatric institute was offered to an American who was working Pavlov's lab.[30]

W. Horsley Gantt (1892–1980)

Gantt was born in Virginia and had studied at the University of North Carolina, before enrolling for a medical degree at the University of Virginia. On obtaining his MD in 1920, Gantt joined the American Relief Administration in St. Petersburg to study the impact of the war and resultant famine. In 1922, knowing of Pavlov's work on digestion, he made a visit to Pavlov's lab; see Figure 1.6. There Pavlov explained his research on conditioning to the 30-year-old who had hitherto known nothing about the topic. Gantt reported that this meeting with Pavlov "stirred me emotionally, immediately made to believe that here was the method of studying mentality and its disorders." After completing further medical training in the UK, he returned to Russia as soon as he could and spent the next four and a half years working in Pavlov's laboratory.[31]

Adolf Meyer learned of Gantt's work and invited him to set up a Pavlovian laboratory within the Henry Phipps Psychiatric Clinic at the Johns Hopkins Medical School in Baltimore.[32] From 1929, when Gantt took up his appointment, he remained the

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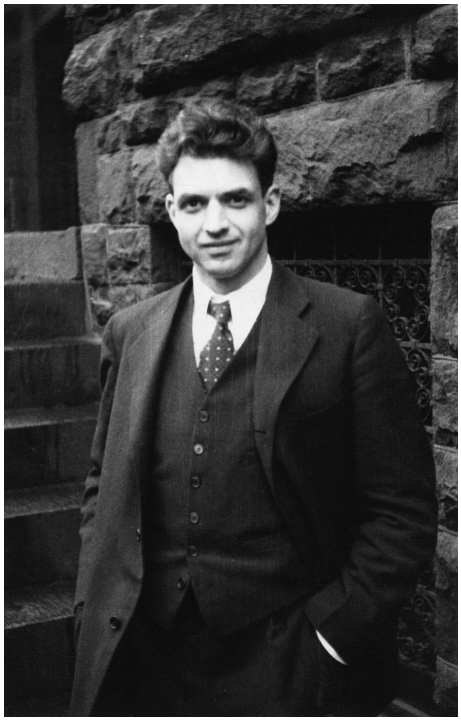

Figure 1.6 W. Horsley Gantt around the time when he first visited Pavlov. Reproduced with permission of the Alan Mason Chesney Medical Archives. Johns Hopkins Medical Institutions.

most prominent advocate of Pavlov's ideas in the USA. In 1930 Gantt established the Pavlovian Laboratory within the Psychiatric Clinic and continued to conduct research and supervise the students who worked in the lab until he was retired in 1967. Despite retirement, Gantt was able to continue his experiments until shortly before his death in 1980, leaving only one other of Pavlov's students still alive.[33] Perhaps because his return to St. Petersburg occurred a few months after the great flood, a time when Pavlov's main enthusiasm was to explain mental illness in terms of his conditioning theory, a major focus throughout Gantt's long research career was on psychopathology.

Gantt's book on the *Experimental basis for neurotic behavior*[34] reported a replication of Shenger-Krestnovikova's experiment on experimental neurosis produced – in this case – by training a dog to discriminate between ever-closer frequencies of a metronome. It also included the description of a traumatizing event akin to that of the St. Petersburg flood; in this case, his dogs had escaped one night from their enclosure and roamed the building, until discovered by a night watchman who clubbed them back into their kennels. Subsequently some dogs performed poorly in their conditioning experiments; "the inhibitory reflexes were much more unstable."[35] By contrast, some seemed unaffected; for example, Billy, who was judged to have "a strong, well-balanced nervous system."[36] The bulk of this book, however, was devoted to

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recounting the life and experimental treatments of a single dog, Nick, over a period of nine years starting in February, 1932. What to conclude from this mass of detail is hard to make out.

Like Pavlov, Gantt appears to have had little interest in developing conditioning methods to use as therapy for any kind of mental illness. Gantt's one paper that referred to treatment of experimental neurosis reports that a dog recovered after being given a few mild shocks.[37]

When I met Horsley Gantt in 1975, he expressed some bitterness that his work had not received the recognition that he felt it deserved, together with sadness that what he referred to as the "Pavlovian school" had never taken root in America. Perhaps he had discovered that only one of his papers was cited in an authoritative review of research on Pavlovian conditioning published the previous year.[38]

Gantt's coauthor of this paper was William Brogden.[39] In the long run Brogden was to become better-known than Gantt as, allegedly, the first person to investigate *sensory preconditioning*.[40] As described more fully in a later chapter, in experiments Brogden carried out in Gantt's Pavlovian Laboratory dogs were first repeatedly exposed to pairings of two neutral stimuli, A->B, and then B was paired with shocks; when A was then presented in a test, the dogs showed fear, even though A had never been paired with shock. This result implied that the dogs had learned that B follows A in the first stage of the experiment.

Although textbooks ever since have credited Brogden's 1939 report with being the first account of sensory preconditioning, in fact the phenomenon had been subject to a series of experiments in Pavlov's lab in the early 1930s,[41] as noted below. They were not cited in Brogden's report. In 1928, Gantt had published his translation into English of a set of lectures that Pavlov had given over a 25-year period, starting with the 1903 lecture in Madrid.[42] It seems that either Gantt no longer maintained in touch with what was happening in Pavlov's lab or he failed to tell Brogden about the Russian experiments on sensory preconditioning.

Many of Gantt's experiments were an extension of the kind of research he had carried out in Pavlov's laboratory. However, unlike Pavlov, Gantt mainly studied conditioning of cardiovascular responses and of leg flexion. Some experiments involved the conditioning of responses to drugs.[43] Later in his career, he and his students were the first to suggest that Pavlovian conditioning provided an explanation of placebo effects.[44]

Gantt can be seen as someone who fell between two disciplines. When he addressed psychiatrists and told them about his research,[45] it is unlikely that many found that this helped them to solve the clinical problems they confronted. And not many psychologists, even psychobiologists, are likely to have found talk of "collisions between excitatory and inhibitory processes" an appealing way to think about psychological processes.

In 1955 Gantt founded the Pavlovian Society and its annual meetings continue to provide an important forum for researchers studying Pavlovian conditioning. However, it is very doubtful that Gantt would have approved of the content of most of the papers presented at this meeting since 1980, let alone of the language used.

Howard Liddell and Conditioning Research on the Behavior Farm

The second important proponent of Pavlov's ideas in the USA was Howard S. Liddell (1895–1962). Like Gantt, Liddell also visited Pavlov in the early 1920s in the city recently renamed as Leningrad. However, unlike Gantt, Liddell had both an undergraduate and Master's degree in psychology and the purpose of his visit was to learn more about Pavlov's experiments on conditioned reflexes.

Liddell was born in Cleveland, Ohio and raised in Erie, Pennsylvania. After obtaining his Master's degree from the University of Michigan in 1918, he decided to enroll for a Ph.D. at Cornell University, but in physiology instead of psychology. His advisor there, Sutherland Simpson, specialized in the study of the thyroid gland in farm animals, especially sheep.[46]

In view of Liddell's undergraduate training in psychology, he was persuaded by his advisor to test whether the cretinism produced by removing a sheep's thyroid reduced its ability to learn simple tasks. To investigate the idea Liddell constructed a series of mazes to test both normal sheep and those that had had their thyroid glands removed on their ability to learn their way through a maze to access a food reward. The experiments were not a success. "From our point of view we did not have adequate control of the experimental situation. The sheep and the goats in the maze were doing what *they* wanted to do … It was not pleasant on a cold winter's day to watch a lethargic sheep lie down in the snow at the junction of the alleys and remain there for almost an hour before proceeding on its way."[47] Liddell looked for a better way to study his animals' learning abilities. In 1923, a lecture given at Cornell by a former student of Pavlov, Gleb Anrep, led Liddell to the idea that conditioning methods could provide the answer. Hence, his first visit Pavlov in 1926.[48]

Liddell started to carry out conditioning experiments with sheep in the Physiological Field Station that Simpson had established. Thus, the Field Station became the first laboratory in the USA for the study of Pavlovian conditioning. Liddell's research attracted generous grants from both the Macey and the Rockefeller Foundations and as a result his research program flourished throughout the 1930s. In 1937 Cornell University acquired a 110-acre farm that became Cornell's Behavior Farm Laboratory; its cafeteria, known as the 'Home Dairy,' was where Liddell did most of his writing and where he interacted with research assistants and students. As first Professor of Physiology and eventually Professor of Psychobiology, he could devote most of his time to research.[49]

For the majority of Liddell's experiments the UCS was delivery of a brief, mild electric shock to the foreleg of the animal – "a shock so weak that we could scarcely feel it on the moistened finger tips"[50] – and the unconditioned and CRs were a brief leg flexion. Apparatus for testing lambs is shown in Figure 1.7 and for testing a goat in Figure 1.8.

The first case of experimental neurosis in Liddell's new laboratory occurred by accident. During a routine experiment in 1927 Liddell was impatient to collect more data to report at an upcoming meeting and decided to increase the number of metronome-shock pairings given to a pair of sheep from 10 to 20 each session. The

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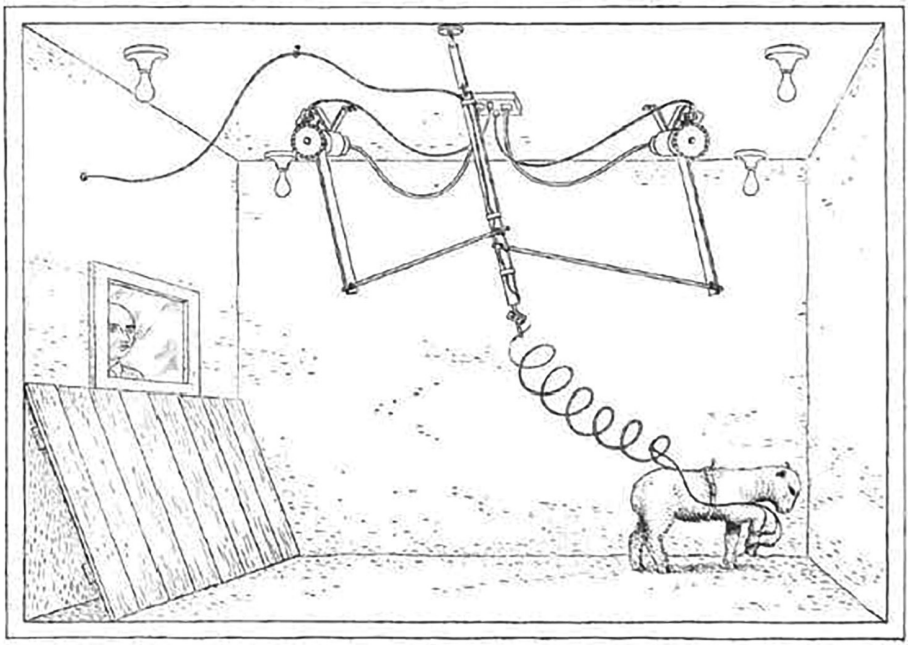

Figure 1.7 Arrangement for establishing a conditioned reflex in a lamb in Liddell's laboratory. From Liddell (1938). Public domain.

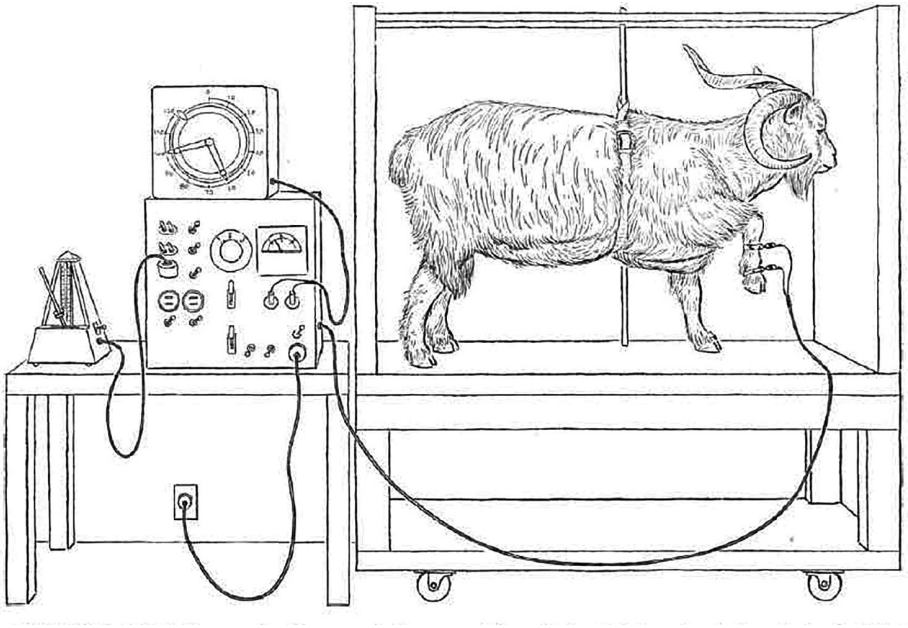

Figure 1.8 Classical conditioning of a goat in Liddell's Behavior Farm Laboratory. From Liddell (1938). Public domain.

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normal sheep suddenly began to display agitated behavior and this persisted even when on subsequent sessions no signals and no shocks were given. Meanwhile, the thyroidectomized twin continued to produce precise conditioned leg flexions and "never exhibited the slightest sign of emotional excitement or alarm."[51] The normal sheep turned out to have acquired a chronic emotional disorder. Subsequent experiments established that the same outcome could be reliably produced in sheep and goats by several other methods. On a visit to Cornell one of Pavlov's assistants confirmed that the symptoms were similar to experimental neuroses seen in dogs.

This topic became the central concern of Liddell's research for the next 25 or more years. He saw the aim of his conditioning experiments on animals to be that of increasing understanding of emotions, rather than of learning processes: "The primitive forces of man's emotions are more dangerous and more devastating than nuclear fission. Who can doubt that the central scientific problem of our time is the problem of emotion."[52]

Like Pavlov, Liddell believed that the study of disturbed behavior in animals would provide a scientific basis for understanding human neuroses and what later become known as post-traumatic stress disorder (PTSD). This belief was strengthened when at 57 years of age Liddell visited Korea during the height of the Korean War to interview soldiers who had returned from the front.[53] He appears to have been widely liked and respected by his students and peers; "No one who knew Howard Liddell is apt soon to forget his ebullient, bustling manner, his earthy anecdotes … and the man who responded with sensitiveness and perceptiveness to the needs of his colleagues and friends."[54] In the 1960s, one student of Liddell's, Jeff Bitterman, became very influential; see Chapter 5.

Jules Masserman and Joseph Wolpe: From Neuroses in Cats to Behavior Therapy

Pavlov used dogs almost exclusively in his experiments on conditioning. In doing so, he was following the tradition of nineteenth century experimental medicine, the tradition in which his training and early professional career had been based. In the USA Pavlov's near contemporary, Edwin Thorndike, used cats as well as dogs, and later, monkeys, in his pioneering experiments on instrumental learning.[55] Some of Thorndike's successors also used cats in experiments designed, for example, to test their problem solving abilities, their visual acuity or whether they possessed color vision.[56] The first reports of experimental neuroses in cats were published in the late 1930s. In one such study the researchers attempted to train six cats to open a food-box within 10 seconds of a repeated light-and-bell signal; if they took longer, an electric shock was delivered. The five that failed to learn to respond in time developed behaviors that were labeled 'neurotic' and persisted for at least two months.[57] This report appears to have inspired the influential series of studies by Jules Masserman.

Masserman (1905–1989) was a young boy when his family emigrated from Poland to the USA prior to World War I. Rejecting the prospect of working in the family

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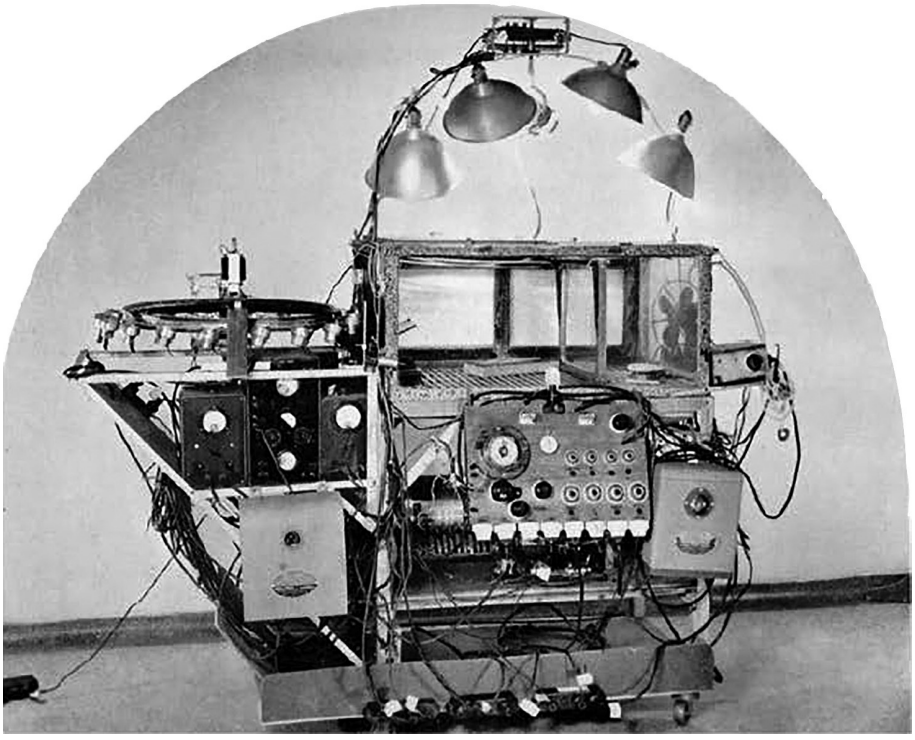

Figure 1.9 Apparatus used by Masserman to establish experimental neuroses in cats. From Masserman (1943). Public domain.

tailor shop in Detroit, he spent 10 years studying medicine, later specializing in neurology and psychiatry, before obtaining a residency in 1932 with Adolf Meyer in the latter's Psychiatric Clinic. It was during his three years there that Masserman learned about Gantt's work on neuroses in dogs. Although impressed by Pavlov's and Gantt's experiments, Masserman was highly critical of Pavlovian theory.[58]

In that era training in psychiatry was strongly influenced by Freud and other psychoanalytic theorists. Nevertheless, there was widespread belief that psychiatric practice needed to be based on better evidence than that provided by Freudian analysts; in other words, it needed to be more 'scientific.' Masserman shared this belief and became convinced that the study of neuroses in animals would contribute to satisfying this need. His ambition became "to demonstrate that all animals adapted to their environments in ways that demonstrated psychoanalytic principles, particularly the internalized response to stresses and conflicts."[59]

It was not until 1942 that Masserman began to realize this ambition. By then he had become a member of the Department of Psychiatry at the University of Chicago and had undergone training in psychoanalysis. He set up a lab in which he could run experiments that were intended to produce neuroses in cats and test ways of then curing them. His apparatus is shown in Figure 1.9.

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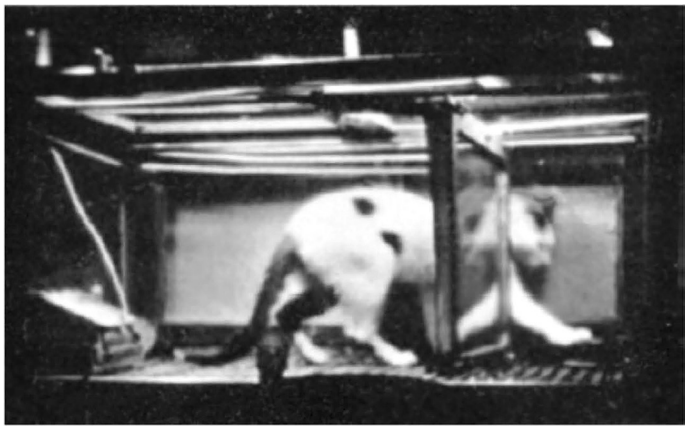

Figure 1.10 One of Masserman's cats.
From Masserman (1943). Public domain.

Masserman believed that neuroses – or 'nervous breakdowns' – resulted from conflict. During World War II he treated many soldiers relieved of their duties and sent back to America because of what in World War I had become known as *shell shock,* then *war neurosis* in World War II, and very much later was termed *post-traumatic stress disorder* (PTSD). He believed that this state was caused by the conflict, for example, between escaping from a life-threatening situation and continuing to do one's duty on behalf of comrades and one's country.

Many of Masserman's hungry cats were faced with a conflict between obtaining the food they had earned by depressing a switch several times and being subject to a blast of air as they lifted the lid of the food box. For others the conflict was between obtaining an earned food pellet and receiving an electric shock as they crossed a grid to reach the food box.

Such treatments were regarded as successful in producing a neurosis if a previously quiet cat subsequently "tended to show restlessness or agitation" or a previously active cat "developed marked restriction of activity and a tendency to passivity." Another cat commenced "a fidgety, incessant" movement. Masserman also identified "phobic," "counterphobic," and "regressive" behavior patterns; see Figure 1.10. He claimed that the therapy he provided to such cats was based on the psychoanalytic concept of *transference*. Sometimes this consisted of simply providing a cat with a lot of attention and petting. A less humane treatment – but an interesting one in the light of subsequent developments – was to force the cat – for example – to cross the no longer live grid to obtain a food pellet and confront its fear.[60] Later, Masserman tried electro-convulsive shock, alcohol and the sedative, sodium pentothal, as potential therapies.[61]

As noted earlier, Masserman's ambition was to provide a more secure scientific basis for psychoanalytic-based treatments, but his experiments were poor science even by the standards of the 1940s. In terms of later standards, the lack of any details in his reports of methods or results, the absence of criteria for deciding whether some

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behavior was neurotic, the lack of an observer who was blind to the treatment a cat had received, these and further weaknesses would have made his research unpublishable. Nevertheless, Masserman's career flourished. Grants from the US Public Health Service allowed him to expand his lab, first in Chicago and then at Northwestern University, and to include monkeys as subjects in addition to his cats. For example, hungry rhesus monkeys served in experiments on 'altruistic' behavior, in which most animals chose to avoid making a response that would have given them access to food, if this also resulted in the delivery of an electric shock to a second monkey that could be seen through a window looking onto an adjoining compartment.[62]

Masserman's professional career also blossomed as his research became widely known, helped by the films of his animal experiments that he circulated and by his appearances on radio and television, and as his ideas on 'biodynamic psychiatry' were increasingly accepted. In 1979 Masserman was appointed President of the American Psychiatric Association. But in the same year, his career suddenly ended in disgrace; he had treated one of his patients with sodium pentothal and, when she woke up from her trance, she discovered that "he was having sex with her."[63]

In the long run the most influential by far of researchers inspired by Pavlov's reports of experimental neurosis was a South African, Joseph Wolpe (1915–1997). He was born in Johannesburg, where he undertook medical training at the University of Witswatersrand. During the Second World War he served as a doctor in the South African Army. His efforts to treat soldiers suffering from PTSD guided his decision to specialize in psychiatry and study experimental neuroses when the war was over. His doctoral project began with a comprehensive review of research on experimental neuroses, defining these as "unadaptive responses that are characterized by anxiety, that are persistent and that have been produced experimentally by behavioural means."[64] The review was followed by a report of a year's worth of experiments starting in June, 1947, that were inspired by Masserman's early research on the topic. Unlike Masserman, Wolpe rejected Freudian theory after finding during the war that therapies based on such theories were ineffective.[65]

One method used by Wolpe was similar to one that Masserman had used. Six cats were first trained to approach a food cup, in which minced beef pellets were delivered whenever a buzzer was sounded; once a cat was consistently producing the conditioned approach response, Wolpe now delivered an electric shock each time the animal was about to seize the food pellet. As Masserman had found, this produced changes in the cats' behavior that generalized well beyond the experimental setting. One important new result emerged from Wolpe's inclusion of a control procedure whereby six cats were exposed to a simple conditioning procedure in which the sound of a hooter was paired with shock delivery in the absence of any conditioning of a feeding response. This simpler procedure produced many of the same symptoms as the Masserman procedure. The less surprising ones included anxiety when placed in the cage and "refusal to eat meat pellets anywhere in the cage even after 1, 2 or 3 days' starvation."[66] Even introducing the cats into rooms other than the experimental room could produce signs of anxiety; its intensity was found to vary with the degree to which the new room resembled the experimental room.

Wolpe was interested in what "curative measures" would be effective in relieving his cats' neurotic behavior. "The fact that the neurotic reactions of the cats were associated with inhibition of feeding suggested that under different conditions feeding might inhibit the neurotic reactions: in other words, that the two reactions might be reciprocally inhibitory."[67] One method was to feed a cat in the room that was least similar to the experimental room and, once this was successful, to feed it in the second least similar room and so on, until the cat behaved quite normally even in the experimental room.

Wolpe reported that his "experience of the past 4 years has encouraged belief in the hypothesis that experimental and clinical neuroses are parallel phenomena. … The human subject is not often forced to undergo his conflicts or his traumata in physically confined space. He is usually kept in the anxiety-producing situation by the force of habits previously learned. For instance, a woman entangled in a humiliating marriage may be unable to get out of it because her earlier training has given a horror to the idea of divorce. Besides confining her within the marriage, this feeling of horror, being in conflict with escape tendencies, makes possible the development of a high level of emotional tension (anxiety). This tension becomes increasingly conditioned to contiguous stimuli through the drive reductions that follow every partial escape from the causative situation."[68]

Wolpe found that a curative measure similar to the one he had used with his cats could be effective in treating patients suffering from anxiety disorders.[69] He knew that this procedure had been first used in New York in the 1920s by Mary Cover Jones, a graduate student supervised by John Watson. This time the procedure was not forgotten. *Systematic desensitization* has been routinely and successfully used very widely for the treatment of phobias and other kinds of anxiety disorders ever since. Thus, it took over 40 years from Pavlov's report of experimental neurosis to the widespread adoption of a therapy that Pavlov's experiments inspired.

Following the publication of his 1952 paper, Wolpe's animal research, his Pavlovian-sounding theory of *reciprocal inhibition* – neither a cat nor a human being can be both anxious and relaxed at the same time – and the form of therapy that his research inspired became very widely known. He spent 1956/57 as a visiting fellow at the Center for Advanced Studies in the Behavioral Sciences at Stanford University, where he had considerable contact with another fellow, the philosopher, Karl Popper. The latter persuaded Wolpe of the need to make theories testable. In 1960 Wolpe returned to the USA and remained there for the rest of his life.[70]

Chimpanzees and Problem Solving: Pavlov's Final Years

The great passion of Pavlov's final years was the creation of a scientific center in the village of Koltushi, some 22 kilometers east of Leningrad. In the early years of its development Pavlov and his assistants traveled there by train. Later, he was driven there and back in the Lincoln limousine that, together with a chauffeur, was permanently on call, just one more element of the increasing generosity which he enjoyed from Stalin's government.

In Koltushi, "the Soviet state erected to his specifications a science village that combined two of his great loves, science and rural dacha life. This Institute of Experimental Genetics of Higher Nervous Activity housed a grand project to study the relationship of heredity and environment to constitution and temperament, and, eventually, to turn this knowledge to practical use in the upbringing of children and the breeding of an improved human type."[71]

Soviet generosity was accompanied by increasing influence over the research carried out in Pavlov's multiple labs. There was a steady increase in the proportion of coworkers, assistants and students who were committed communists. One or two were influential in their arguments, based on dialectical materialism, that Pavlov needed to study brain processes in primates and not confine himself to dogs. Pavlov's death was shortly followed by Stalin's 'great purge,' when many of Pavlov's former coworkers, whether communist party members or not, together with several of his friends and influential contacts in the government, were either shot or sent to the gulag.[72]

Returning to Pavlov's research in the early 1930s, a new interest was in Gestalt psychology and its challenge to associationism and American behaviorism. He and Wolfgang Koehler, whose 1919 book on *The mentality of apes* Pavlov had at least partly read, were the main invited speakers at the Psychology Congress held in New Haven in 1929.[73] At the age of 84, Pavlov began to study the two chimpanzees, Roza and Rafael, that arrived in Koltushi in 1933.[74] The two were given many of the problem-solving tasks that Koehler had described. Their behavior convinced Pavlov that they were more intelligent than his dogs, but he attributed this to the dexterity they enjoyed as a result of having effectively four 'hands.' Pavlov had no time for Koehler's claim that chimps' problem-solving involved insight – a "fictitious muddle" – and instead believed that it could be explained in terms of associations.[75] His work with the two chimpanzees and the experiments on what became known as *sensory pre-conditioning*, as described earlier, led to Pavlov to decide by 1935 that associations and conditioned reflexes were not different labels for the same processes.[76]

Many years passed before these changes in Pavlov's ideas became known in the English-speaking world. In July 1935 Pavlov began a 10-day trip to address the International Neurological Congress in London. Instead of reporting experimental results from his multiple labs, the topic of his address was "Types of higher nervous activity in connection with neuroses and psychoses, and the physiological mechanism of neurotic and psychotic symptoms."[77]

Pavlov died in February 1936.

Jerzy Konorski: Type 2 ('Motor') Conditioning and His Critique of Pavlov's Theories

Like Gantt, Jerzy Konorski (1903–1973) was a non-Russian whose life was completely changed on learning about Pavlov's research. Unlike Gantt, Konorski's huge respect for Pavlov was not uncritical. He rejected both Pavlov's theories of the neural

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processes underlying conditioning and Pavlov's long-standing claim that the conditioned reflex was the only form of learning.

Konorski and his friend, Stefan Miller (1903–1940), were medical students in Warsaw, Poland in the mid-1920s when they first read about Pavlov's experiments on conditioning. "The starting point for our investigations was the fact, known from everyday life, from training experience and from the evidence of behaviourist psychology, that if an animal's motor reaction leads to a 'satisfying state of affairs' (Thorndike) then it tends to be repeated in the same situation, but if it leads to an 'annoying state of affairs,' then it tends to be avoided. We subjected these generally known and universal facts of animal behaviour to conditioned reflex investigation, analysed them in regard to their structure and, to some extent, in regard to their physiological mechanism."[78]

Their first experiments involved a single dog, Bobek. In an early experiment Bobek stood facing an electric lamp. As soon as the light was switched on, Bobek's forepaw was raised by the experimenter's hand and the dog was fed. After several repetitions of this procedure, Bobek's forepaw raised without human aid as soon as the light was on. The results from a series of more complex experiments convinced them that Pavlov's theory of the conditioned reflex was unable to explain such learning, describing the reasons for this conclusion both in an article published in a French journal in 1928[79] and in a letter to Pavlov sent in the same year. They referred to their form of conditioning as a 'Type 2 Conditioned reflex.' Pavlov initially rejected their arguments and the idea of a second kind of conditioning. However, he was sufficiently interested and impressed to instruct his favorite research assistant, M.K. Petrova, and two students to replicate the Warsaw experiments. He also invited the two Poles to spend time in his lab. They arrived in 1931. Miller was newly married and stayed only a few months. Konorski stayed for almost two years.[80] During that time Pavlov failed to convince Konorski that he was wrong, while Konorski became an expert on the experimental results that had been obtained in Pavlov's lab over the previous two decades and on Pavlov's theoretical explanations for those results. Konorski also acquired the skills needed to run experiments on 'Type 1' conditioning. Pavlov eventually came to accept Konorski's account of 'motor conditioning.'[81]

After they returned from Leningrad, Miller and Konorski obtained positions in Warsaw's Nencki Institute of Experimental Biology, where they set up a conditioning lab to run experiments both on Pavlov's Type 1 and on their Type 2 conditioning. Their work on the latter became known in the English-speaking world in 1937, when they published a paper on the topic in an American journal[82] and became even better known because of the resulting exchange with the American psychologist, B.F. Skinner (see Chapter 8).

Following Pavlov, Konorski and Miller also began experiments on problem solving involving children and monkeys.[83] But these ended in 1939 with the German invasion of Poland. Miller was killed in a Nazi concentration camp and the Nencki Institute was destroyed. Konorski wrote most of a book. With the end of the war, his lab was rebuilt and in 1948 Konorski was able to visit the UK and make the final arrangements for the translation into English and publication of his book; the title was *Conditioned reflexes and neuron organization*.

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Konorski's second hero was the British physiologist, Charles Sherrington, whose studies of spinal cord reflexes eventually earned him a Nobel Prize in 1932. Much earlier Sherrington had introduced the term 'synapse' and had published a book called *The integrative action of the nervous system*. It was this book of 1906 that inspired Konorski, to the extent that in 1967 he gave an almost identical title to his second book, namely, *The Integrative activity of the brain*. For Konorski, like Pavlov, the. point of studying conditioned reflexes was to discover how the brain works. What he set out to do was to make sense of what was known about conditioned reflexes in terms of Sherrington's concepts, such as excitatory and inhibitory synaptic connections between neurons, rather than the concept of the nervous system held by Pavlov, which – as noted earlier – was already generally known to be invalid by 1900. The model of conditioning that Konorski proposed in 1948 anticipated developments decades later.[84]

The neural processes underlying conditioning are beyond the scope of the present book. However, it seems appropriate to provide here one example of how Konorski's explanation of an effect that was first documented in Pavlov's lab differed from Pavlov's own account. As noted earlier, *Stimulus generalization* refers to the finding that, once a CR is established to a CS, other stimuli that are similar to the CS can also elicit the CR, but to an extent that decreases with increasing dissimilarity to the CS. According to Pavlov, the occurrence of a novel test stimulus evokes excitation in its cortical center that spreads out across the cortex with diminishing energy. When this wave reaches the CS center, the resulting excitation evokes the CR. If the wave has traveled a long way – because the test stimulus differs considerably from the CS – then the CR will be weak. Konorski's account was essentially the one that has been accepted ever since. Presentation of the CS excites a large number of cortical neurons, while presentation of a test stimulus excites a proportion of the same neurons that is related to how similar the test stimulus is to the CS. In Konorski's words: "It must be assumed that the cortical centres of particular stimuli represent complex and widely dispersed formations, that they overlap, and that this partial overlapping is the cause of generalization."[85]

To criticize Pavlov during the Stalin era could end a scientific career. "Pavlov, although he was never a member of the communist party, was a representative of progressive science; his views were considered 'errorless,' and no change in his theory could be tolerated."[86] Pavlov's successors in Russia, such Asratian, were careful not to depart from their teacher's theories. In contrast, Konorski wrote: "the above-mentioned defects, they seem so obvious to us that it is difficult not to perceive them. And yet even today many of Pavlov's disciples and followers, hypnotized by his theory, either do not see, or else do not want to see them."[87] Somehow Konorski survived public attacks on his views and personal threats. He re-established the small research institute that he had founded just before the war in order to continue experiments on conditioning.[88] With the death of Stalin his career and the Nencki Institute flourished, as described in Chapter 9.

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