in Chapter 3, we do find this— the brain is electrically activated in sleep and, when this happens, the mind is turned on too. Naturally. It's that simple.

A more detailed example should clinch our point. If, in our exploration of the brain in sleep, we find physiological evidence that memory systems are disabled, we should expect to find that memory is altered during dreaming and that dreams would be difficult to recall. We already know that the second prediction is true, but just how true we cannot yet say precisely. The first prediction has, however, scarcely been entertained. Is it generally true that I cannot exercise my episodic memory when I am dreaming? Does this affect dream content?

These examples are chosen to highlight two important points about the doctrine of brain–mind isomorphism. One is that it is just as fruitful to map from the brain to the mind as it is to map from the mind to the brain. The second is that we must choose carefully the appropriate level of each domain at which to focus our isomorphic efforts. In the beginning, and we are still very much at the beginning, we will find that global and psychologically general levels will be more generous than detailed and psychologically personal ones. Individual differences have never been generous to psychology. And how many of them are real? Although it may disappoint you if you hanker after a fortune-telling interpretation of your dreams, our attention to the mirrored formal aspects is necessary to the scientific understanding of dreaming as a universal process. Later in this book we will see how it can be used to help individual dream interpretation by relieving it of an impossibly difficult task and helping us to discover the usually clear emotional salience of our dreams.

3

How is the brain activated in sleep?

Consciousness is so rapidly and dramatically reduced during sleep that it was natural to assume that the brain simply turned off at sleep onset and turned on again just before awakening. Indeed, some people do sleep all night in that deep, oblivious, and uninterrupted way. Some, but by no means all. And no one sleeps that way all the time. There are periods of life change and stress when mental activity seems to go on all night. Are these to be attributed to our not really being able to sleep at such times? Perhaps. But what about dreaming? How could such elaborate and exciting mental activity arise in an inactive brain?

This question was answered in a wide variety of erroneous ways. As dream recall was generally poor and needed awakening to be present at all, many scientists—Sigmund Freud among them—wrongly assumed that dreaming occurred only in the instant before awakening. Now it is certainly true that dreaming can occur just before awakening. And we have already noted that

dreaming can be so unpleasantly exciting as to provoke awakening, leading to another erroneous assumption: that all dreams are unpleasantly exciting, i.e. all dreams are characterized by negative emotions such as anger, anxiety, or fear.

Another erroneous theory was that dreaming arose in response to external sensory stimuli that were strong enough to activate the brain, but not strong enough to produce arousal. Again it is true that train whistles, indigestion, and spouses coming home late can influence dream content. But they often don't, and dreaming doesn't depend on such stimuli even when they do gain entry to the sleeping brain.

It turns out that most dreaming occurs under the calm cover of sleep and is the result of a built-in mechanism of brain activation that operates in all of us every night of our lives. It is the goal of this chapter to explain how the brain activation of sleep was discovered and how it gradually initiated the paradigm shift, or change in pattern, from dream content to dream form that has been the subject of my first two chapters. Before beginning our story, it is important to appreciate that, just as it took a full half-century (1900–53) to recognize the reality of brain activation in sleep, it has taken another half-century (1953–2001) for us to come to terms with this discovery. And there are still many diehards who refuse to relinquish the hopeless fantasy of the total power of interpretation offered by dream content analysis.

Why did it take so long to discover brain activation in sleep?

We are inclined to assume that it is the slow progress of technological development that impeded scientific advances in studying

dreaming. But this is a face-saving sop for those who were so conceptually blinded that they could not imagine the simple experiments that could have led to the brain activation conclusion. As Michel Jouvet shows in his novel *Château du Rève*, most of our vaunted twentieth-century discoveries about sleep could have been made earlier by the most useful scientific instrument of all: direct observation. The direct observability of sleep is especially easy to achieve in our infants and children, the very individuals who most dramatically reveal the brain activation of rapid eye movement (REM) in their behaviour.

And it almost happened, although never quite. Instead of simply observing sleepers—and seeing with one's own eyes the periodic occurrence of small facial and eye movements, as well as muffled cries, penile erection, flaccid muscle tone, depressed spinal reflexes, and a host of other autonomic or self-regulating measures (take respiratory rate for a simple example)—those few scientists who were interested enough to perform anything faintly resembling a sleep or dream experiment interfered with the sleep of the participants in their studies. It was the induction of dreaming that these scholars, most of whom were French, were interested in. Could they induce a participant to dream of a certain odour by opening a perfume bottle under his or her nose? The answer was yes, as they found out, but it was very, very difficult. And, meanwhile, they missed the chance to observe natural sleep.

We must admit that staying up all night observing other people sleeping is not everyone's idea of fun. It requires unusual motivation and a modicum of self-discipline, even if one is tempted by the prospect of discovery. If Freud had only imagined that dream behaviour could be observed—he was certainly motivated enough to do it—he would quickly have realized that

all he needed to do to be a sharp observer was to sleep in the daytime. His phobic concern about suggestion could have been further quieted by the premium placed upon doing nothing but watching.

But, in reality, it's even easier than that. For anyone to observe REM sleep behaviour directly, it can be done with bed partners, especially in the wee hours of the morning, most conveniently on vacation, in the summer time when the hillock of the cornea can be seen in the early dawn light to glide to and fro under the closed—or perhaps half-open—eyelids. The eyelids themselves dance and twitch sporadically and, when they do, one has only to give a light tap on the shoulder and ask what is going on in the mind. Informed consent is as admirable in these informal conditions as it is in university sleep labs, but don't let that stop you.

If you don't have a willing bed partner, you can observe your big sister's baby or anyone's pet cat or dog, and have the same thrill of discovery. Of course you can't expect an answer if you ask *them* if they are dreaming. But you can answer that question for yourself now that you know that the REMs that give brain-activated sleep its most popular name are a direct readout of the internal activation. Not that dreaming occurs exclusively in REM sleep. It doesn't. REM sleep just happens to provide the most ideal condition for its occurrence.

In Chapter 4, we take up the question about the dreaming brain that, so far, only our animal collaborators can answer; in Chapter 5, we consider the implication for the development of the abundant, florid REM sleep of all mammalian newborns. My point here is simple and descriptive. The first step of any natural history endeavour is to observe (quietly and carefully) and to record one's observations (thoroughly and systematically). It is

as embarrassing as it is instructive that this was never done by anyone aspiring to either sleep or dream science before 1930. How many other breakthrough discoveries now elude us because we are conceptually boxed in by gratuitous assumptions that there is nothing to observe and/or that we can obviate direct observation via intuition or speculation?

The electroencephalogram and the sleep lab

Neurophysiologists were every bit as slow as psychologists to move dream science forwards. They knew about reflexes but they didn't know about spontaneous activation. Instead they assumed that the brain was as dependent on stimulation for all of its activated states as was the mind in sleep.

Two of the greatest minds in the history of science studied reflexes and believed that mental activity was stimulus-dependent. The Nobel Laureate Charles Sherrington argued, forcefully, that the reflex was the functional unit of the brain. He never really listened to his imaginative student, Thomas Graham Brown, who tried to convince Sherrington that it was the spontaneous activity of paired 'half-centres' that set the stage for reflex responsiveness. The basic difference between Sherrington's reflex and Graham Brown's half-centre concept is that the reflex brain was completely dependent upon external stimuli, unlike the half-centre brain which was capable of spontaneous activity. Sherrington made the mistake of assuming from his own conscious experience that his brain simply turned off when he went to sleep.

Ivan Pavlov, justifiably famous for showing that reflexes can be conditioned, shared Sherrington's assumption that the mind was blank in sleep (wrong!) because the brain was inactive

(wrong again!) and unstimulated (wrong once again!). As we see in Chapter 4, it was not until well after the discovery of REM sleep that the activation of the nerve elements known as neurons (neuronal activation) was shown to be continuous in sleep. This means that our brains never turn off completely, and hence they are always capable of *some* level of mental activity, even if waking and dream consciousness both depend on a robust level of brain activation.

Electrophysiology began to correct the picture in 1928 when the German psychiatrist Adolf Berger succeeded in recording brain waves from the surface of his patients' heads using an amplification and recording device that came to be known as the electroencephalograph (or EEG). The EEG revolutionized sleep and dream science as much as it altered clinical neurology because it provided an objective tool for assessing dynamic brain activity in normal individuals as well as in patients with epilepsy. Figure 2 illustrates an EEG, together with other variables used in modern sleep science. Against great scepticism that his so-called 'brain waves' were artefacts of movement or muscle activity, Berger won the day when he showed that the EEG underwent distinctive changes in sleep. To cut a long story short, behavioural sleep was invariably associated with a tendency for the brain waves to slow (in frequency) and to increase (in amplitude). This change marks the onset of what we now call slow wave or non-REM (NREM) sleep.

It wasn't long before the EEG was used to study sleep in the forerunners of today's sleep labs. The capacity to record physiological variables has grown so dramatically in the twentieth century that we tend to forget how simple the early devices were, and how startling the discoveries made with them. Today's 'polygraphs' are all direct descendants of Berger's baby, a

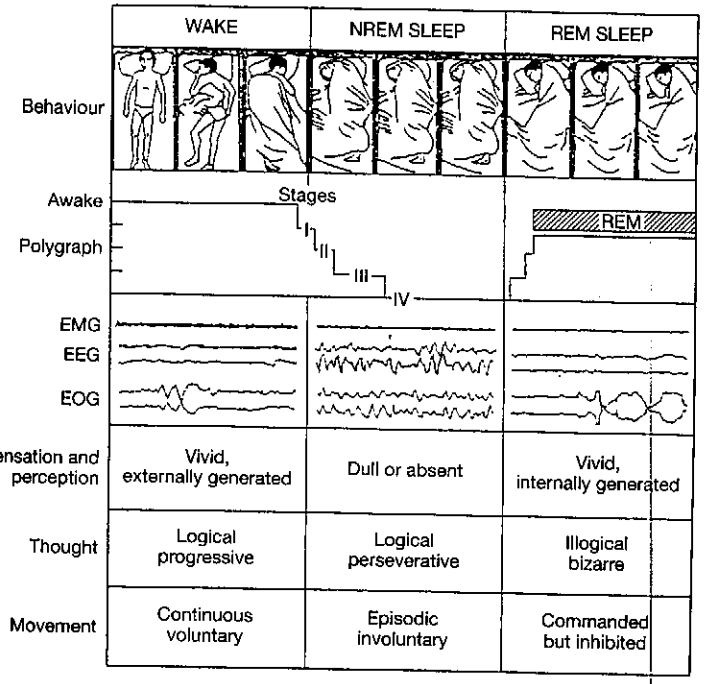


Figure 2 Behavioural states in humans. States of waking, NREM sleep, and REM sleep have behavioural, polygraphic, and psychological manifestations. The sequence of these stages is represented in the polygraph channel. Sample tracings of three variables used to distinguish state are also shown: electromyogram (EMG), which is highest in waking, intermediate in NREM sleep, and lowest in REM sleep; the electroencephalogram (EEG) and electro-oculogram (EOG), which are both activated in waking and REM sleep and inactivated in NREM sleep. Each sample is approximately 20 seconds.

glorified voltmeter that can raise the power of electrical signals three orders of magnitude from the microvolt (thousandth of a volt) range on the surface of the body to the volt range of the recorders. Variations on the theme of EEG are its better-known

predecessors, the electrocardiogram (ECG), which measures the heart's activity, and its two offspring, the electro-oculogram (EOG), which measures eye movement, and the electromyogram (EMG), which measures muscle tone.

How was brain activation in sleep discovered?

It was the combination of EEG and EOG that enabled Eugene Aserinsky and Nathaniel Kleitman to make their 1953 discovery of brain activation in sleep. They called the brain activation phase of sleep REM (for rapid eye movements) because of the association of the activation of the eye movements (oculomotor activation) with activation of the brain. They asserted that dreaming might be another associated event. It was the EMG (together with the EEG and EOG) that allowed Michel Jouvet and François Michel to show that muscle tone supporting posture—and hence postural movement—was actively abolished in REM sleep.

Before 1953, it was recognized that sleep was not uniform/intractable, any more than it was inert. In other words, electrical patterns of brain-wave activity changed continuously, denoting both global and local flows of brain activation. It was assumed, erroneously, that only the intense brain activation of REM was capable of sustaining dreaming. As the REM periods occurred periodically at 90-minute intervals and occupied 1.5 to 2 hours per night, this seemed like more than enough time to accommodate dreaming. It is certainly many times more than the instant before awakening.

It turns out, however, that dreaming can also occur at sleep onset (no surprise because the EEG is still relatively activated)

Do we dream in black and white or in colour?

Modern lab evidence suggests strongly that we dream in colour. To what, then, do we attribute the common misperception that dreaming occurs in black and white? The answer is very clear—it is the poor memory. Recall of dreaming is a function not only of brain activation in sleep but also of awakening conditions, which determine whether dreams will be recalled at all, whether they will be recalled clearly, and whether they will be recalled at length. In all clear, lengthy reports we see colour descriptors in abundance. We dream in colour. In our thousands of lab-dream reports, there is not a single instance of a well-recalled dream being in black and white, as would be expected if this were indeed normally the case.

and in other phases of so-called NREM sleep, especially late night stage II sleep when the brain is almost as active as in REM sleep, often called stage I. That leaves stages III and IV, which occur early in the night and are considerably less likely to be associated with dreaming.

The point of this introduction to sleep lab science is to show that, although technology was not really necessary to describe dreaming scientifically or to describe sleep behaviourally (because both could have been done via careful direct observation), it was indispensable in showing that brain activity is continuous—and continuously variable—in sleep.

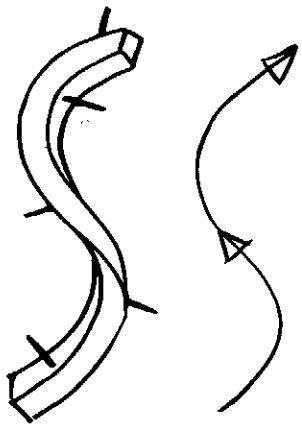
Who discovered REM and the EEG sleep cycle?

Eugene Aserinsky was interested in studying attention in children, so sleep was a nuisance to him because, no matter how hard he tried to keep them alert, sleep invariably took over the minds of his young participants. As many teachers of the young have seen, Aserinsky noticed that when his participants' attention flagged their eyes tended to close. He therefore decided to put electrodes near the childrens' eyes in order to record their eye movements while they were awake, and this helped. Aserinsky was, however, astonished to discover that, when his young participants finally succumbed to sleep, their eyes darted back and forth and up and down behind their closed lids. He had inadvertently discovered REM sleep—and the first participant was his seven-year-old son Armand. Aserinsky was a persistent scientist but he was also just plain lucky. Why? Because REM occurs at sleep onset *only* in children!

As Louis Pasteur opined, 'In the field of observation chance favours the prepared mind'. When Aserinsky reported his observations to Kleitman, his mentor recognized their significance for a science of dreaming. By extending this observation on the eyes into sleep, and by recording the EEG and the heart and respiratory rates in adults, Aserinsky and Kleitman were able to observe the regular ebb and flow of activation affecting the brain, the eyes, the heart, and even breathing throughout sleep. When this activation was maximal—with a wake-like EEG, clusters of REMs, rapid heart action, and fast, shallow breathing—awakenings yielded long, complex dream reports, similar to the one below.

11/7/1981 Country House in Winter, Dream no. 19

We are at a country house in winter, like the farm in East Burke but different. K.D.K. is there and we are skiing. I am looking, with a sexual motive, for A.T. whom I have not seen for at least 20 years and whom I never loved. She may be upstairs in this home, which may or may not be



mine. The second floor is reached by climbing a twisted wooden shaft with inadequate branch-like steps. It is a struggle. When I pull myself up—noting that the heating is on and therefore that the house must be inhabited—I find myself in the arms of a sleeping J.C.

J.C. suddenly wakes up—with a look of not-surprising terror on his face—and tries to orient himself. I see and feel his murderous, self-protective fear as he struggles to decide if I am I, and if I am real. This all happens in an intense instant, summarizing all of the emotional complexity of our relationship. I try to reassure him saying, 'J.C., it's me, I love you.' And. . . .

Dreams with frankly sexual themes such as this one are relatively rare in sleep lab settings, where being the content is more likely to reflect concern about sleeping while being observed and being subjected to awakening. (In fact, this dream occurred when I was on a trip to China and sleeping in a hotel in Guangzhou, of which there is not the faintest record in my dream.) The dream is, however, typical of those reported after awakenings from REM sleep, whether in the sleep lab using the Aserinsky–Kleitman theory, at home using our portable Nightcap monitoring system, or in hotels in Guangzhou, China.

11/7/1981 Country House in Winter, Dream no. 20

I am again climbing toward an ambiguous bedroom. This time the thread of the spiral ascent is to the left upward. There are two routes: one is safe, but long, through grass at the base of a rock butte; I take the other, more vertical and direct ascent on the edge of the rocks. I am glad that I was forewarned (by C.?) that the rock was rotten because I quickly adapt to the succession of slides of large slabs of the cliff side. Each time I take a step, some of the granite falls away. These huge chunks of rock make not a sound as they fall, out of view, to my left. Finally, with relief, I am at the summit, which is a grill-like threshold on to which I level myself with two

hands. I thank my benefactress—hostess (C.?) for having prepared me to cope with this hazardous ascent.

The universal characteristics that this REM sleep dream evinces are intense frequent hallucinations (called hallucinosis in psychology)—in this case the climbing movements are all perilously gripping—and a complete lack of self-reflective awareness. The setting is typically indefinite: it is my house but not really; the characters are vaguely defined—in this case particularly C.; emotions such as fear and elation are strong.

It is as if my brain were activated in a particular, selective way to form hallucinations and emotions that are sensorimotor (coordinating perception and action) in character, causing these elements to be combined in a completely novel but personally meaningful way. This is the 'synthesis' part of the dream process that Robert McCarley and I wanted to identify in our 1977 activation–synthesis thesis. In Chapter 5, we learn more about

evidence for this hypothesis, which can come through the application of imaging techniques to sleep and dream science.

During the early days of the sleep lab era (about 1953–75), the goal was to establish correlations between details of the dream plot, as described by participants, and details of physiology, as described by the EEG or polygraph. I call this the strong one-to-one isomorphic hypothesis, which attempts to link mental activity to peripheral physiology in real time. The goal was not achieved. Thus, early claims that the eye movements of REM sleep could be predicted from the sequence of directional changes in the dreamer's hallucinated gaze could not be substantiated. Although dream content did occasionally reflect the sudden increases and decreases of respiratory efforts, as would be expected in turning, talking, or painting, more often it did not.

In retrospect, the failure of this ambitious theory is not surprising: it never worked very well in waking either. It perpetuates the notion of the philosopher and psychologist William James, who held that emotion was the perception of peripheral physiology (e.g. anxiety occurs when I sense my rapid heart rate). This idea was discredited and eclipsed by Walter Cannon and Philip Bard's centralist theory of emotion, which says that the feelings that we have are a function of selective activation of that part of the margin of the brain known as the limbic brain (see Figure 11); they may then be associated with a wide variety of peripheral physiological changes.

An even more serious disconnection between dream psychology and brain physiology was threatened. When first David Foulkes, and later many other psychologists, reported that dreaming *could* be associated with almost any EEG stage of sleep, they reached the unlikely conclusion that the mental activity of dreams had nothing to do with sleep neurophysiology. Believe it

or not, this mind–brain dissociation hypothesis is still passionately defended. Needless to say, most of those who held these views were the disappointed champions of strong content analysis; some were even die-hard Freudians, and none was a practitioner of physiological sleep science.

Among the many compelling reasons to reject the assertion of brain–mind dissociation is the still overwhelming evidence that REM sleep is the most favourable base for fully realized and sustained dreaming; that NREM sleep is at best only half as favourable; that sleep onset is even less so; and that while awake, dreaming is essentially impossible. At this stage of our scientific knowledge all we can say is that dreaming is increasingly probable if the several brain conditions of REM sleep are present. The psychological counterpart of this correlation is given by the formal analysis and not content analysis of dreams. In dream reports we therefore seek to measure the degree to which they are hallucinatory (not what is seen) or thoughtful (not what is thought).

What is the biology of sleep and dream science?

Meanwhile, even as the dream debate grew fractious and became sterile, the sleep lab was unearthing a treasure trove of physiological findings of great interest to dream science, as well as to behavioural biology generally. The Aserinsky–Kleitman discovery was made in 1953, the same year that Watson and Crick published their epochal double-helix model for DNA. There are two important implications of this coincidence. One is that biology came of molecular age at the same moment that dream

science came of physiological age. In the subsequent half-century, biology has changed beyond recognition—in fact, it is now in danger of becoming nothing but the molecular biology of the gene.

Sleep and dream science, meanwhile, has only begun to approach molecular biology in terms of either conceptual ideas or methodology. This is both because the descriptive task of sleep and dream science was so enormous and because the concepts that were drawn into the field, especially from psychology, were not equal to the scientific opportunities presented. Not everyone, even today, wants to make mental activity physical. Too many cultural and private belief systems are threatened by the idea that consciousness in dreaming, as in waking, is a brain function. The immortality of the soul is a prime example. If the brain dies, doesn't the mind die with it?

One idea that the biological revolution in dream science forces us to take seriously is that, although it constitutes an undeniably interesting and informative state of altered consciousness, dreaming has no particular function in and of itself. As conscious experience, dreaming is nothing but our occasional awareness of brain activation in sleep. In this view, it is the brain activation underlying REM sleep itself that performs the vaunted functions of dreaming: establishing psychic equilibrium, integrating recent and past learning, casting our inventory of personal information in emotionally salient (or relevant) terms. All of these important functions can and certainly must be performed whether or not we are aware of them. If they depended on our conscious awareness of dreaming, we would be in big trouble—especially those who have no dream recall whatsoever.

The burden of proof now falls clearly, and heavily, on those who maintain that an awareness of dream content actually helps

us. For example, I am enlightened by finding through recall of Dream no. 19 that my psychosexual conflicts with a former friend and his wife are still alive in my mind. But, even if my interpretation of this dream is correct, how does it help me to know this fact? By making me aware that yes, after all, there is an unconscious, or that yes, after all, sexuality *is* polymorphous and ambiguous—that despite superficial appearances to the contrary, all is not entirely kosher in Hobson's unconscious mind.

Such sophistication might endear me to my psychoanalytic brethren, leading to a wider acceptance of my ideas, increased book royalties, and even referral of patients. Thus, my physical survival as well as my intellectual procreation could be enhanced. But it seems far more likely that I would do as well, or better, if I never had my spiral staircase dream or, rather, never recalled and therefore never interpreted it—the 'dream work', if any, is done unbeknownst to me, by REM sleep and its friends in my unconscious brain.

This is just the kind of 'reductionism' that psychologist opponents of physiologically based dream theory fear. Foulkes has argued passionately against what he perceives to be 'physiology's effort to take the problem of dreaming off of psychology's hands'. To some extent he is correct. If the main formal features of dreaming can be shown to be physiologically determined, then content analysis does not have to account for them. Instead of lamenting this situation, however, dream psychology could do well to breathe a heavy sigh of relief at seeing this onerous burden lifted. Freud himself was pushed to the psychoanalytic wall in trying to explain dream hallucinosis as a psychological defence. His effort to explain poor dream memory in terms of active repression (rather than simple amnesia) was equally forced. Worst of all, his effort to account for dream

emotion in terms of either wish fulfilment or disguise fell flat on its face because so many dreams contain unpleasant negative affect and because so many are undisguised.

Reductionism was Freud's strong suit. He tried to explain, as all would-be scientists do, the greatest number of variables in terms of the fewest assumptions. In hitting upon his wish fulfilment–disguise censorship model he was reductionist in the extreme. *Every* steeple is a phallus. *Every* dimple is a vagina. The problem is that Freud's reductionism was wrong, and it was wrong, in large part, because he did not observe behaviour, measure neurological function, or collect dreams systematically using the mind-set and tools of natural science.

Now, we have the facts of human sleep physiology. Now, we know—beyond the shadow of a doubt—that our consciousness in waking, sleeping, or dreaming is a brain function. It is high time to move on and to create the great, bold, and neurobiologically based theory to which Freud himself aspired. Reductionism cannot explain away phenomena. Dreaming will always be vivid, bizarre, emotional, unreasonable, and hard to remember. But how (the question of mechanism) and why (the question of function) may be explored scientifically using physiological tools. As content analytical dream theory reveals, it is the danger of circularity that has given subjectivity a bad name. Now we have a brave new world of scientific dream theory in which circularity can be transcended and dreaming can still be enjoyed, discussed, and interpreted.

In this chapter, we take seriously the idea that it is REM sleep that constitutes the ideal physiological conditions for dreaming, and attempt to use the data collected in cellular and molecular level studies of sleep in animals to answer the how and why questions of dreaming in greater detail.

4

Cells and molecules of the dreaming brain

By 1890, the scientific world was aware that the brain consisted of billions of individual cells called neurons (100 billion at the last count). In the first half of the twentieth century, while sleep and dream science were being prepared at the more global level of the electroencephalograph (EEG), neurobiologists were learning more about neurons than had even been imagined in anyone's speculative philosophy—and that anyone includes Sigmund Freud, Charles Sherrington, and Ivan Pavlov.

Among other things, by 1950 it had become clear that, as each neuron was bounded by a semipermeable membrane, it had the capacity to concentrate an electrical charge across that membrane by actively pumping ions such as sodium, potassium, and chloride in and out of the cells. This membrane potential, as it was called, could be raised (inhibition) or lowered (excitation) as a result of the influence of chemical molecules secreted by neighbouring neurons, which delivered their influences via