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MEDICAL PROGRESS

THE D-STATE (Concluded)

A Review and Discussion of Studies on the Physiologic State Concomitant with Dreaming

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PHARMACOLOGY AND THE D-STATE

A great many data, mostly from small informal studies, are available concerning the effect of drugs on the D-state, but as yet no definite pattern has emerged. A number of substances decrease the amount of time spent in the D-state. This is true in man for phenobarbital and several other barbiturates studied so far.[20] Phenothiazines likewise tend to decrease D-time; trifluoperazine (Stelazine) has some confusing early effects[54] but probably actually decreases D-time like the others.[55] Alcohol has been shown to cause a decrease in D-time,[56] and in fact it has been suggested that delirium tremens may represent a state of acute "rebound" from dream deprivation — that is, the patient has had his D-time suppressed over a prolonged period while drinking, and the vivid hallucinatory state when he finally stops drinking represents an effort to "catch up" on D-time.[57,58] The authors present evidence for increased D-time after withdrawal from alcohol, but this is, of course, during sleep: the delirium-tremens condition is certainly not a typical D-period but might be seen as the condition of a "waking dreamer" in whom somehow both the mechanisms underlying the D-state and those underlying waking are operating at once.

Since hypnogenic and tranquilizing drugs have been shown to decrease D-time, it was thought that stimulants such as caffeine or the amphetamines might have the opposite effect. However, this does not turn out to be the case: caffeine apparently has little effect[56]; dextroamphetamine sulfate definitely reduces D-time, when it allows the subject to sleep at all.[59]

These studies have been done on man, but it appears that in general these groups of drugs have the same effect on cats; in addition it has been shown that large doses of atropine effectively suppress D-periods in cats[18] and rats.[60]

Thus, a variety of drugs appear to be able to depress D-time; it would certainly be useful to have a drug that would increase D-time or at least provide sound sleep with a normal amount of D-time, in view of the dangers of dream deprivation, but no such drug has yet been found. However, large doses of eserine, an acetylcholinesterase inhibitor, have a tendency to increase the length of D-periods in cats although total D-time is not definitely increased.[18] Lysergic acid diethylamide (LSD) has been found to have little effect, or if anything to decrease D-time in cats,[61] but a recent study shows that within a very narrow dosage range, it may lengthen at least one D-period during the night in man, without increasing total D-time for the night.[62]

Although there are no drugs that definitely increase D-time, one may with reasonable ease achieve a night of increased D-time pharmacologically by administering for a time, and then withdrawing, either phenothiazines, alcohol or dextroamphetamine sulfate.

Altogether, the pharmacologic findings do not point to any clear-cut conclusions as yet, except perhaps the conclusion that the D-state is quite

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fragile in the sense that it can be suppressed fairly easily either by drugs that increase sleep (S-sleep) or by those that increase wakefulness. In addition, the findings on atropine and the acetylcholinesterase inhibitors suggest that a cholinergic mechanism may be involved. This is supported, though only indirectly, by a number of reports on the effect of DFP (a potent cholinesterase inhibitor) in man[63]; one of the most common effects noted is "excessive dreaming" although, of course, this refers only to dream reports, since no electroencephalographic studies were done.

Neurochemistry of the D-State

This is a field of inquiry that does not yet exist, but in my opinion it must make its appearance soon, since a recurrent, regular, basic biologic state such as the one under discussion, characterized by a well defined neurophysiologic picture, almost certainly must have central chemical changes underlying it. And there are certain tentative indications of what neurochemical substances or mechanisms may be implicated.

Jouvet[18] has reported, though this has not been confirmed by other investigators, that it is possible to set off a D-period of fifteen to twenty minutes in cats by a very brief electric stimulation of the central pons during S-sleep and that after such a D-period there is a refractory period lasting for ten to fifteen minutes during which one cannot set off another D-period. Of course, this must be interpreted cautiously: it may mean only that one can set off a D-period by stimulation at just about the time another period would have appeared spontaneously. However, if one accepts these findings, the length of time involved suggests a neurohumoral mechanism; taking into account the previously mentioned findings on atropine, eserine and di-isopropyl fluorophosphate (DFP), one might conclude that acetylcholine is probably involved, at least in the discharge of the D-periods. This is hardly a very novel suggestion, however, since acetylcholine discharge is involved in many, or most, multineuron events in the nervous system.

Several kinds of evidence suggest that, in addition to this mechanism, there may be some substance that gradually accumulates during waking and nondreaming sleep and is then discharged or metabolized during D-periods; acetylcholine itself does not behave in this way, but another substance might build up and at a certain level act to stimulate certain areas and release acetylcholine. Evidence for this possibility comes first of all from the dream-deprivation studies mentioned previously[48]; it certainly appears in these studies that a "need to dream" builds up during the deprivation period. This is also supported by the informal finding in many laboratories that a patient who gets to bed much later than usual, or has slept poorly the night before, tends to have his first D-period much sooner after falling asleep than usual, as though he had built up a "need to dream." A study of the relation between the length of a nondreaming sleep (S) period and the length of the subsequent D-period also bears this out: the finding is a positive correlation between the length of the S-period and of the following D-period, with the subject, time of night and other conditions held constant, but there is no correlation between a D-period and the following S-period.[64] This again implies that a "need to dream," actually a need for D, builds up during S, so that, other things being equal, a longer S period is followed by a longer D-period. Jouvet's cats with a complete destruction of the pontine nucleus (RPC nucleus) are also relevant here: these animals, as mentioned, continued to have ordinary-looking waking states and S-states but no longer had D-periods. They lived only a few months, during which they manifested a condition characterized by increasing tachycardia, agitation and episodes during which the cats looked about curiously, wiped nonexistent objects with their paws and appeared to the observers to be probably hallucinating.[18,30] The cats finally died in an apparently toxic condition after a period of coma. Again, this suggests the possibility that something that eventually became toxic to the animal was gradually accumulating during the prolonged time without D-periods.

All these studies, of course, only indicate the existence of an accumulable "tendency to have D-periods"; there is no present evidence that this "tendency" is actually represented by a chemical substance although this is perhaps the simplest explanation. Certainly, a combination of substances, the lack of a substance or altered sensitivities of certain cell groups might explain the facts as well. But to speculate further and assume that the accumulation of one or more substances is involved, are there any hints of what substance it might be? Two possibilities come to mind, both of them substances that are found in the central nervous system, might build up in the way hypothesized and could act as neuromodulators — a term used by Freedman[65] to describe a substance that is not directly released at nerve endings, as true neurotransmitters are, but whose level in the nerve cell somehow influences events at the nerve endings and synapses. One is GABA, gamma-aminobutyric acid, and its claim to consideration comes from the tentative finding that gamma-butyrolactone, a closely allied substance, causes sound sleep with normal D-periods[30] and a recent report that the administration of sodium butyrate, very close to GABA in structure, may induce D-periods in cats.[66]

The other possibility is serotonin. The effects of LSD previously referred to, some very recent work on the effects of tryptophane[64,67] and reserpine[64] on the sleep-dream cycle and a great deal of indirect evidence[64] lend support to the possibility that serotonin is involved. Several of the so-called "paradoxical effects" of serotonin (for instance the fact that substances that increase brain serotonin levels seem to produce first a period of slow-wave electroencephalographic patterns, followed after a few minutes by low-voltage, fast activity) can perhaps be explained on the basis that increased brain or brainstem serotonin levels produce a "tendency to have D-periods" rather than either general "excitation" or "depression." But this is a very complex question that cannot be discussed in detail here and will, it is hoped, soon be elucidated by work in progress. This section has been intended only to indicate one field of inquiry that will probably become important in the near future, and some speculation has necessarily been involved.

D-State and Mental Illness

Hughlings Jackson wrote: "Find out about dreams and you will find out about insanity."[68] Jung[69] said, "Let the dreamer walk about and act like one awakened, and we have the clinical picture of dementia praecox." Freud,[1] of course, carried the same idea farther in his conception of primary process thinking. Therefore, when it was first discovered that one could determine objectively, by the electroencephalogram and eye movements, when a person was dreaming, it was believed that this would provide a key to the study of schizophrenia, or at least an excellent diagnostic test. It was clear that the amount of "dream time" should be very different in schizophrenia, though a good a priori argument could be made for changes in either direction. It was predicted that schizophrenic patients might not have dream periods at all during sleep since they "did their dreaming" while awake; on the other hand it was predicted that they obviously had a tremendous "need for dreaming" and thus should show far more D-time than other people. The facts, unfortunately, do not support either speculation, at least in the extreme forms cited above. Studies by Dement,[6] Feinberg et al.[70] and others on large mixed groups of schizophrenic patients have shown a mean D-time of about 20 to 25 per cent — the same as that in normal subjects. A further disappointment was that even hallucinating schizophrenic patients had normal D-times, as did those with very acute schizophrenia, at least in the series reported by Koresko, Snyder and Feinberg[71] and Feinberg and his associates.[70] A group of 6 middle-aged depressed patients likewise showed normal D-time.[20]

However, these negative results may not represent the entire picture: Rechtschaffen and Verdone[72] have reported a slight but significant correlation between anxiety, measured by the Taylor Manifest Anxiety Scale, and D-time in a population of college students. Fisher and Dement[73] mention a group of borderline patients whom they studied who consistently show a D-time of about 29 per cent, well above normal levels. They also report a case of a paranoid patient who normally had fairly high levels, around 30 per cent, whose D-time rose to over 50 per cent one night as he was becoming psychotic. Unfortunately, the patient had received trifluoperazine that day, which produces a confusing electroencephalographic picture when first administered, and therefore the actual D-time for that night was probably much lower than reported. However, these studies do give some reason to suspect that a high D-time may be associated with stress or certain forms of stress. A study of identical twins, discordant for schizophrenia, showed a much higher D-time, about 30 per cent, in the schizophrenic twin, although twins were expected to show quite similar records.[55] One long-term study of individual psychotic patients under standardized conditions, attempting to relate several measures of D-time with various ratings and measures of psychologic state, has also been conducted.[74] One manic-depressive patient in this study showed definitely high D-time when he was very depressed, with a gradual fall to normal as he improved; he did not have any manic periods during the twelve months of the study. Results on 2 other patients, 1 of whom was definitely schizophrenic and 1 borderline, did not show such a straightforward correlation.

Thus, the relation between mental illness or stress and amount of D-time is far from clear although there are a few positive hints that D-time may be related to stress or depression. Of course, it cannot be certain that one is really dealing with something significant when merely D-time is studied — perhaps some persons can somehow achieve twice as much "dreaming" or "discharge" in a given time as others; however, the work on D-deprivation and on length of D and S periods suggests that time spent in D is an important variable. There have been studies of other characteristics of the sleep-dream records of psychotic patients, such as the actual number of eye movements within D-periods, but these have not been very productive. One finding that has struck me as well as others is that the D-periods are not as clearly demarcated in schizophrenic patients as in normal persons. It is hard to decide from the record just where a D-period starts or ends since there are transitional periods sometimes marked both by signs of D, such as rapid eye movements, and signs of S-sleep, such as spindles. However, this is probably not specific to schizophre-

nia since it appears to some extent in the records of anxious subjects and those sleeping in the laboratory for the first time.

It was also thought that if indeed schizophrenia resembles dreaming, perhaps some of the electroencephalographic and physiologic criteria of the D-state could be found in schizophrenic patients while they were awake. The results so far have been entirely negative,[75] but this may be because only very crude and peripheral measures that can be applied to human subjects are available.

One other possible relation to mental illness concerns the onset of psychotic episodes. In these situations a patient is anxious and disturbed for a variety of reasons: he is unable to sleep or sleeps poorly and thus probably deprives himself of D-time to some extent; this makes him feel worse — more anxious; and a vicious circle may be set up. Furthermore, a patient in a prepsychotic state often has frightening dreams that quickly awaken him, thus further depriving him of D-time even if superficially he appears to be getting enough sleep. The possibility should be considered that some of the symptoms associated with acute psychosis, such as excessive fantasies and visual hallucinations, are actually a result of superimposed D-deprivation, rather than part of the underlying psychiatric problem. Here, a drug is badly needed that will tranquilize and allow sleep, but without depriving the patient of further dreaming.

D-State and Dream Content

Now that much of the work on the D-state, the physiologic organismic state concomitant with dreaming, has been reviewed and commented on, the discussion may return to the starting point, the dream itself, and consider what light these studies have shed on the experience of dreaming.

There have been a large number of such studies on dream content, stimulated by the ability to tell objectively when a subject is dreaming, and they cannot all be reviewed here. What this review will do is consider some of the most frequent and most interesting questions about dreaming and indicate what answers have been found or are being sought by work in progress.

One obvious question is whether the characteristics of the D-state, such as the eye movements, pulse, blood pressure and respiratory changes, have anything to do with the dream content. Do the dreamer's eyes move back and forth constantly if he is dreaming of watching a tennis match, for example, and does he stop breathing for a few seconds when he sees something startling or frightening in his dream? The answer at present is a tentative "yes." As far as the eye movements are concerned, there are various informal reports of dreams that involved a great deal of motion and were also found to include many eye movements on the record. One study has been done, involving only a few subjects, however, in which highly verbal, intelligent subjects were awakened from a D-period and asked to describe carefully just what they were looking at for the minute before awakening. From this report, judges who had not seen the records tried to predict how the subjects' eyes should have moved if they had indeed watched the scenes described for one minute. There was a very good correspondence between the predicted eye movements and the subjects' actual recorded eye movements.[76] Incidentally, this study also strongly supports the present point of view that dreaming takes time — about as much time as watching the same events in waking life, in fact — and that one does not have a long dream in an instant.

The evidence for the other physiologic changes is not so good as that for the eye movements. Again, there is anecdotal evidence about very exciting dreams associated with large changes in pulse or respiratory rate; the only systematic study so far found a significant but not a very strong general relation between respiratory variability and the vividness or emotionality of the dream.[77]

However, it must be remembered that eye movements and changes in pulse and respirations also occur in decorticate cats and human beings,[18,78] in whom there is almost certainly no subjective experience of dreaming. Thus, perhaps the best formulation at present would be to say that a primitive state, the D-state, necessary to all mammals, involves eye movements and a general autonomic outflow, whether or not accompanied by the subjective experience of dreaming, but when this experience is present, it is somehow synchronized with the physiologic changes. The various possible patterns of feedback between activity in the visual cortex, which is presumably concomitant with the visual dream experience, and the physiologic changes and eye movements, cannot be discussed here.

Another interesting question is whether there are systematic differences between dreams at different times of night. It appears at present, from studies by Rechtschaffen et al.,[13] that there are such differences — specifically that dreams occurring later in the night, or nearer morning, tend to be more vivid, more emotional, more bizarre or, in other words, more "dreamlike." Further work is in progress to determine whether such vivid dreams are primarily associated with time of day, with amount of previous time in bed or with low body temperature.

A further question in this area would be whether the content of the four or five dreams on the same night is related in some way. Again, there are many anecdotal reports of content relation and some more formal studies[79,80] indicating that often the same

content reoccurs or, more frequently, that the same problem is dealt with in successive dreams. At times the expression of the problem becomes more and more direct in successive dreams on the same night.

Another question of interest is whether external events can influence dreams or initiate dreams. It appears that an external stimulus, such as a sound, a light or a jet of water on the skin, can indeed be incorporated into the dream content, in about 20 to 60 per cent of the cases, if introduced during a D-period.[81] This has been confirmed informally in a number of laboratories, and it is possible that the percentage of incorporations would be higher if symbolic or greatly distorted incorporations were considered as well as the direct incorporations usually sought. Thus, a stimulus presented during a D-period can definitely be incorporated into the dream content; however, it has never been possible to initiate a D-period by introducing any kind of external stimulus during nondreaming sleep.

One final question, since all human beings under normal conditions spend approximately the same amount of time dreaming (about ninety minutes a night in young adults), is what is responsible for the tremendous differences in how much dreaming people claim to experience — a range all the way from "I've never had a dream in my life" to "I dream every night, sometimes several times a night.

The difference apparently does not lie in the amount of subjective experience accompanying the D-periods as they occur, since even someone who claims never to dream finds, to his surprise, that upon being put to sleep in the laboratory and awakened during a D-period, he does generally remember a dream that seems very like the dreams of others who normally recall their dreams.

Evidently, the differences must lie in the ability to remember one's dreams under ordinary conditions. There have been several studies comparing groups of "recallers" — subjects who frequently recall their dreams — and "nonrecallers."[8,82] It appears that "recallers" may have a little more D-time, on the average, but these differences are very slight. More important, there are general differences in personality between the two groups: chiefly it seems that the "recallers" are more introspective, more interested in the workings of their minds and more tolerant of ambiguity than the "nonrecallers." In addition, more superficial, often conscious factors also obviously play a part in the recall of dreams. For instance, it is well known that a patient in psychoanalysis, whose analyst asks him about his dreams, will usually begin to recall more dreams; likewise, a conscious interest in dreams, in someone doing research on sleep and dreams, for example, is usually associated with increased dream recall. Also, frequent awakenings during the night are associated with greater recall, since a dream will generally be remembered if an awakening of at least a few minutes in length occurs during or soon after a D-period. Some persons claim that they dream only when they are ill or upset; this phenomenon is almost certainly the result of increased dream recall due to frequent awakenings during the night.

Conclusions

The D-state has been examined from a number of points of view, and conclusions have generally been drawn as the discussion progressed. It is clear that dreaming is associated with a basic biologic state, here called the D-state. Knowledge in this field is rudimentary, but it is growing rapidly and in many directions at once, like a young octopus. This discussion has attempted to indicate some of the directions of growth and what the tentacles seem to be grasping.

A few words should perhaps be said about the function of the D-state since the question of function always arises sooner or later. The answer is simple: the function of the D-state is not known, but in the context of present knowledge, the question does not seem a very useful one. It is much like asking the function of sleep or of waking, states that are much better known and whose function can still be argued endlessly. Certainly, it appears that the D-state is necessary for life, as are presumably the states of waking and sleeping, and in this sense its function is to keep the organism living; this is not a very specific or useful answer, however. One will probably achieve more by not asking for one basic function but by examining the various functions or roles of this state in the integrated functioning of the organism's chemistry, physiology and psychology. Even if it should be definitely proved, as seems possible, that there is a chemical substance that is somehow used up or destroyed during D and is toxic if not destroyed, one should not be satisfied with the formulation that *the* function of the D-state and of dreaming is to destroy a toxin.

One more comment on function is suggested: all the studies mentioned so far provide no grounds for accepting or rejecting Freud's basic thoughts on the dream itself — the formulation of the meaning of the dream as the fulfillment of an unconscious wish and the language of the dream as primary process. However, Freud's theory that the function of the dream is the preservation of sleep is open to question, since in fact stimuli threatening to disturb sleep and wake the sleeper never appear to initiate a dream. In this sense the dream or the D-state functions only to preserve itself. Also, the psychoanalytic formulations implying that certain aspects of the dream are due to the prevailing state

of sleep should perhaps be re-examined in view of the present concept that the dream does not really occur in the state of sleep, but in a state of its own, the D-state.

It has been said that the study of dreams is a fool's errand, but it appears possible that this fool's errand will eventually lead the patient fool through the tortuous pathways of insanity, along the royal road to the unconscious and even across the shaky bridge between mind and body.

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Massachusetts Physicians Art Society

110. *Scallop Shack*

(Exhibited at Annual Meeting of the Massachusetts Medical Society, 1965)

Watercolor by

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