our experiments by condensation of acetaldehyde with epinephrine or norepinephrine have not yet been studied.

We observed TIQ alkaloids by fluorescence microscopy in the adrenals of rats treated in vivo with methanol, a metabolic precursor of formaldehyde (*23*). In 1961, McIsaac (*24*) reported the presence of a 1,2,3,4-tetrahydro-β-carboline alkaloid in the urine of rats treated with ethanol, 5-methoxytryptamine, iproniazid (a monoamine oxidase inhibitor), and disulfiram (an aldehyde oxidase inhibitor). The Pictet-Spengler condensation of acetaldehyde with tryptamines to form tetrahydro-β-carbolines is analogous to the condensation with catecholamines to yield TIQ alkaloids; if formed in tissues, the tetrahydro-β-carbolines could play a role in alcoholism analogous to the one we postulate for the TIQ alkaloids.

Our experiments demonstrate the relative ease of formation of TIQ alkaloids in adrenal tissue. Other areas where these alkaloids might form are in adrenergic fibers of the sympathetic nervous system and brain. These alkaloids retain the original catecholamine structure, but ring closure prevents free rotation of the ethanolamine side chain; if the resultant conformational state were to correspond to that required for binding to smooth muscle or brain receptor sites, these substances could be unique neurotransmitter or blocking agents. Since the TIQ alkaloids were not lost during the final perfusion of the glands with saline, it appears that they may be bound in tissues, perhaps at the same loci as the catecholamines. If so, they would be in a unique anatomical location to function physiologically, although present in small amount. We suggest that the TIQ alkaloids, either actively secreted or leaked from nerve termini, contribute to the behavior changes caused by alcohol. The characteristic neurological disturbances, such as hyperexcitability, tremulousness, hallucinosis, and seizures, which occur when concentrations of alcohol in the blood are falling or absent, could be due to the persistent physiologic actions of the TIQ alkaloids. In this way, the actions of these alkaloids could underlie the process of physical dependence and addiction in alcoholism.

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26. We thank D. Dembiec, J. Marcus, E. Dicker, and F. Cabbat for technical assistance. Supported by PHS research grants MH-17071 and HE-01045 and training grant MH-10315. A preliminary report of our work has been presented (*13*).

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Physiological Effects of Transcendental Meditation

Abstract. *Oxygen consumption, heart rate, skin resistance, and electroencephalograph measurements were recorded before, during, and after subjects practiced a technique called transcendental meditation. There were significant changes between the control period and the meditation period in all measurements. During meditation, oxygen consumption and heart rate decreased, skin resistance increased, and the electroencephalogram showed specific changes in certain frequencies. These results seem to distinguish the state produced by transcendental meditation from commonly encountered states of consciousness and suggest that it may have practical applications.*

For thousands of years philosophers have held that it is possible for man to attain "higher" states of consciousness through meditation techniques. At present, scientists are investigating the physiological changes that take place during some of these practices and the practical applications that they may have.

During the practice of various techniques of meditation, expert Zen monks decreased their rate of respiration, oxygen consumption, and spontaneous Galvanic skin response (GSR), and their pulse rate and blood *p*H showed a slight increase (*1*). The electroencephalograph (EEG) record was predominantly alpha-wave activity (even with eyes half open). The alpha waves progressively increased in amplitude and decreased in frequency, and occasional theta activity was noted. When repeated trials of click stimulation were given, there was no habituation of the alpha blocking response (*2*). Studies of autonomic functions in "practitioners of yoga" in India showed a lower breath rate, an increase in skin resistance, and no consistent changes in heart rate and blood pressure during various practices (*3*, *4*). The electroencephalogram of yogis during meditation showed an increase in alpha-wave amplitude and activity, and in a few of the yogis studied there was a loss of the alpha blocking response to all external stimuli (*5*).

Investigators have reported difficulty in obtaining expert practitioners of meditation and in taking measurements in a way that did not interfere with the subjects' contemplative or concentrative efforts (*4*). Transcendental meditation as taught by Maharishi Mahesh Yogi was investigated for the following reasons. (i) It is claimed by the proponent that all practitioners immediately experience beneficial physiological changes (*6*). (ii) Subjects report that the technique is easy and enjoyable and does not involve concentration, contemplation, or any type of control and that they therefore find no difficulty in meditating during the experiment. (iii) A large number of subjects were readily available who had received consistent and uniform instruction through an organization that specializes in teaching this technique (*7*).

The technique is defined as "turning the attention inwards towards the subtler levels of a thought until the mind transcends the experience of the subtlest state of the thought and arrives at the source of the thought" (*8*). The technique involves no suggestion, mental control, or physical manipulation (*9*). The instruction is given personally by a teacher qualified by Maharishi Mahesh Yogi (*7*). The technique is normally practiced twice a day for periods of 15 to 20 minutes; during the practice the subject sits in a comfortable position with eyes closed.

A sample of 15 "normal" college students (that is, with no mental or physical disabilities), whose practice of the technique had ranged from 6 months to 3 years, was arbitrarily selected. Each subject sat quietly with eyes open for 5 minutes and then with eyes closed for 15 minutes; he meditated for 30 minutes, continued to sit with eyes closed for 10 minutes, and then sat with eyes open for 5 minutes. Oxygen consumption was measured in nine of the subjects by either the open- or closed-circuit methods (*10*). In both cases a large mouthpiece and low resistance nonrebreathing valve were used. In the closed-circuit system air was circulated by an air-tight pump operating at 10 liters per minute. A 6- or 13-liter Collins respirometer was used to record changes, and O_2 was added periodically to keep the mixture of air slightly above ambient oxygen concentration.

In the open system, gas was collected in a Collins 120-liter Tisot spirometer, and samples were analyzed in triplicate with a Beckman Physiological Gas Analyzer Model 160. The electrocardiograph (ECG) tracing and skin resistance were recorded by a Grass Model 5 polygraph, and the EEG tracing was recorded by a Grass Model 6 electroencephalograph. Beckman silver–silver chloride and Beckman gold-plated electrodes were used. The GSR electrodes were placed across the palm, and the EEG electrodes were placed according to the international 10–20 system at F_p1, C_z, T3, P3, O1, and O2. Recordings were monopolar, with the reference electrode attached to the opposite ear and a ground over the mastoid bone. The EEG recordings were made on an Ampex Model FR1300 tape recorder, digitized by the Data Processing Laboratory of the Brain Research Institute at UCLA, and then submitted to the UCLA Health Science Computer Facility for spectrum analysis by the BMDX92 program. In several of the EEG studies, sound and light stimulation were given at irregular intervals (varying from 20 to 120 seconds) to test habituation of alpha blocking.

Oxygen consumption, measured by either the open- or closed-circuit methods, decreased in all subjects within 5 minutes after the onset of meditation. The mean decrease was about 45 cm^3/min, or about a 20 percent decrease from the control period. Oxygen consumption remained low during meditation and rose toward the resting level after meditation (see Fig. 1 and Table 1). In measurements made by the open-circuit method there was a mean decrease in total ventilation during meditation of about 1 liter/min. The respiratory quotient (the ratio of the volume of CO_2 eliminated over the O_2 consumed) was in the basal range and did not change significantly throughout the experiment (Table 1). The observed decrease in total ventilation was caused by either decreased frequency of breath or tidal volume, varying from subject to subject.

Skin resistance increased markedly at the onset of meditation, with some rhythmical fluctuations during meditation; it decreased to the resting value after meditation (Table 1). Electrocardiogram recordings were taken on only five subjects. The heart rate of each of the subjects decreased during meditation, with a mean decrease of 5 beats per minute.

Before meditation, with eyes closed, all subjects showed alpha activity. During meditation the regularity and amplitude of the alpha waves increased in all subjects. In four of the subjects, the alpha waves occasionally changed to a slower alpha wave frequency and in some cases stopped for 2- to 5-minute periods and low-voltage theta waves predominated. A time history of alpha-wave intensity (mean square amplitude) for one subject who showed the characteristic increase in alpha-wave activity and the less common long trains of theta activity is shown in Fig. 2. In almost all subjects, alpha blocking caused by repeated sound or light stimuli showed no habituation. After meditation regular alpha activity continued when eyes were closed, and irregular alpha activity developed when eyes were open.

There are certain aspects of the respiration equipment that may have caused unwanted side effects and minimized the findings. In the open-circuit system there was a dead space of 120 ml (due to the large nonrebreathing valve and large mouthpiece). This large dead space, coupled with inadequate circulation, could have produced an increase of CO_2 in the dead space, thus stimulating breathing and possibly increasing O_2 consumption. During the rest period the circulation was probably adequate to eliminate most of the excess CO_2, but during meditation, with decreased frequency of breath or tidal volume, it is possible that excess CO_2 periodically built up and stimulated breathing. Respiration during meditation may also have been hindered by the large collection of moisture in the nonrebreathing valve after an hour of continuous use. Despite possible difficulties caused by the equipment, the physiological changes recorded during meditation indicate a significant and reproducible decrease in oxygen consumption and metabolic rate.

During sleep there is also a decrease in metabolic rate; the reported decrease in mean O_2 consumption during sleep varies with each investigator (*11*, *12*). These values range from about 20 to 10 percent, three of them showing less of a decrease over a full night's sleep than that which occurs during 30 minutes of transcendental meditation.

The patterns of skin resistance changes during sleep (*13*, *14*) are also different from those seen during meditation. In individuals in whom there is a maintained increase in skin resistance during sleep (*13*), the magnitude and steepness of change is generally less than the change that occurs during meditation.

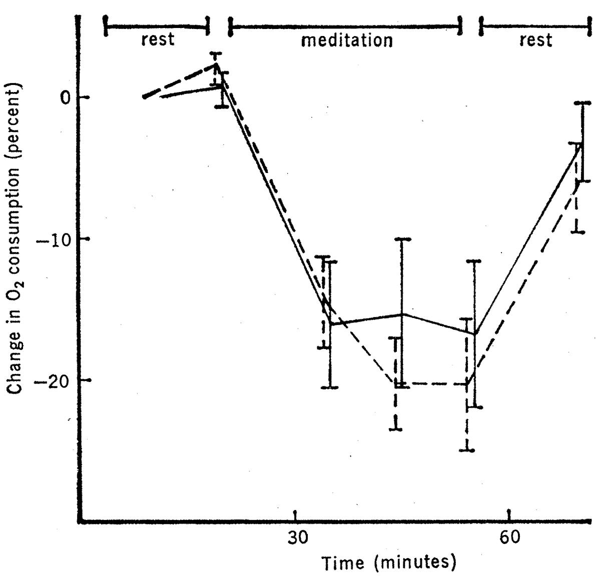
The EEG pattern during meditation clearly distinguishes this state from the sleeping state. There are no slow (delta) waves or sleep spindles, but alpha-wave activity predominates. A few of the subjects showed EEG patterns similar to those found by Kasamatsu and Hirai in expert Zen meditators (*2*). These patterns, which are characterized by large-amplitude alpha waves, by a tendency for the alpha waves to decrease in frequency, and by occasional periods during which alpha activity stops and low-voltage theta activity predominates, are similar to the EEG activity seen in the transition from wakefulness to sleep (*15*). However, this transitional period of drowsiness is usually short and followed by sleep spindles, slow waves, and the loss of consciousness (*15*). Kasamatsu and Hirai interpret the Zen monks' EEG pattern and the nonhabituation of their alpha blocking response as a "special state of consciousness in which the cortical excitatory level becomes lower than in ordinary wakefulness but is not lowered as in sleep and yet outer and inner stimulus is precisely perceived with steady responsiveness" (*2*). Since this type of EEG pattern was only seen occassionally in four of the subjects, it cannot be said at present whether these subjects were drowsy or in the state postulated by Kasamatsu and Hirai.

Table 1. Physiological changes during transcendental meditation. The values given represent the mean for all subjects tested. The resting values are typical for normal subjects (*24*).

Time sequence	O_2 consumption (cm^3/min)	Respiratory quotient	Minute ventilation (liter/min)	Skin resistance (kilohm)
		Resting		
10	246.8	0.86	5.90	91.2
20	244.4	0.87	7.56	101.2
		Meditation		
35	208.1	0.84	5.25	205.0
45	201.9	0.85	5.28	188.8
55	200.8	0.85	5.55	180.1
		Resting		
70	233.1	0.86	5.94	80.2

The physiological state attained in transcendental meditation is different from states induced by hypnosis or autosuggestion. Conflicting studies characterize hypnotic sleep by either an increase, a decrease, or no change at all in heart rate, blood pressure, skin resistance, and respiration rate (*16–18*). The results of these studies and others indicate that the physiological changes induced during hypnosis vary in the same way as in different emotional states observed during wakefulness. Hypnotic sleep following the suggestion of complete relaxation produces no noticeable change in O_2 consumption (*17, 18*). Many different EEG patterns have been reported during hypnosis, but most are identical with wakefulness patterns and all appear to be different from the patterns observed during meditation (*17*).

Recent evidence suggests that conditioning procedures can also alter autonomic functions and EEG patterns (*19–21*). A subject can increase his alpha-wave activity through auditory and visual feedback (*19*). By instrumental techniques animals can learn to control their heart rate, blood pressure, and some endocrine secretions (*20*). Studies on humans have produced some evidence that heart rate, GSR, and blood pressure can be controlled, but the practical application of such procedures needs further investigation (*21*). Expert practitioners of some meditation processes have been found to have some control over certain "involuntary" physiological functions (*1–5*). Although some of these changes could have practical applications, research has been negligi-



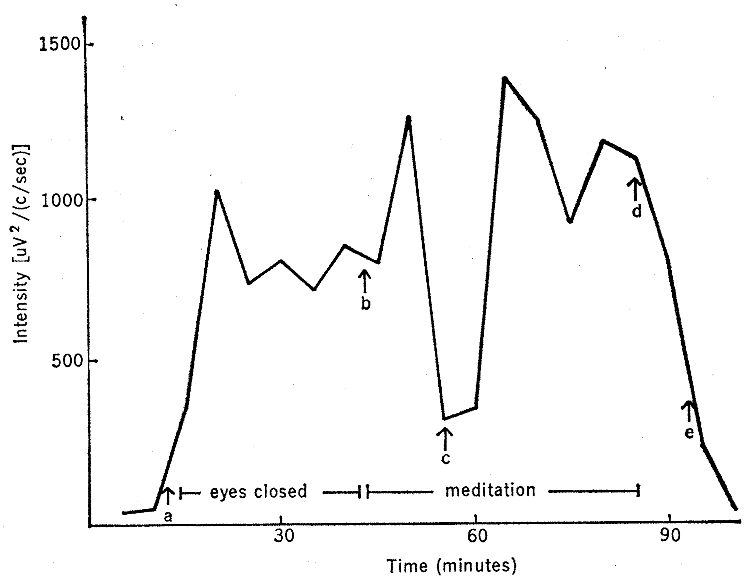


Fig. 1 (left). Percentage of change in O_2 consumption during control and mediation periods. Each point represents the average change in O_2 consumption. The first point was taken as zero percent change, and all other points are calculated as differences from it. The dotted line represents the mean change in four subjects measured by the open-circuit respiration system. The solid line represents the mean change in five subjects measured by the closed-circuit respiration system. Only nine of the fifteen subjects were tested for O_2 consumption changes. The error bars are equal to twice the standard deviation. Fig. 2 (right). A time history of the intensity (mean square amplitude) of an alpha frequency (9 cycle/sec) for one subject. The intensity was calculated from EEG recordings taken from a monopolar lead in the occipital region (C_z). The alpha frequency of 9 cycle/sec was selected as the most characteristic for this subject because it showed the largest alpha-wave amplitude. This subject showed the characteristic increase in alpha-wave intensity and the less common 2- to 5-minute fall in alpha activity. The 2- to 5-minute period, denoted by arrow *c*, showed predominantly low-voltage theta activity. Before arrow *a* the subject's eyes were open; from arrow *a* to arrow *b* his eyes were closed. Between arrow *b* and arrow *d* the subject was practicing transcendental meditation. At arrow *d* the subject stopped meditating and kept his eyes closed until arrow *e*.

ble, owing to the difficulty and impracticality of teaching these processes.

The fact that transcendental meditation is easily learned and produces significant physiological changes in both beginners and advanced students gives it certain advantages over other, more austere techniques. Physiologically, the state produced by transcendental meditation seems to be distinct from commonly encountered states of consciousness, such as wakefulness, sleep, and dreaming, and from altered states of consciousness, such as hypnosis and autosuggestion. Subjective reports coupled with the physiological measurements reported above suggest that this state might have applications to clinical medicine. Transcendental meditation has been reported to have practical therapeutic value in relieving mental and physical tension (*22*). Its value in the alleviation of drug abuse has been suggested, and its value in controlling arterial blood pressure is being investigated (*23*). It could also have other applications—for instance, in space travel and in certain diseases where extended periods of low oxygen consumption that are simultaneous with responsive mental activity would be very useful.

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Paradoxical Sleep in Two Species of Avian Predator (Falconiformes)

Abstract. *Periods of disconjugate and conjugate eye movements occur during the sleep cycle in* Buteo jamaicensis arborealis *and* Herpetotheres cachinnans chapmanni. *Electromyograms are essentially isoelectric throughout sleep. Slow waves appear only in short bursts of low amplitude in contrast to the long trains of high-amplitude waves reported for chickens and pigeons.*

The behavioral and electroencephalographic (EEG) characteristics of sleep and wakefulness in birds are analogous to those reported for mammals, but differ primarily with respect to REM (rapid eye movement or paradoxical) sleep in relation to total sleep time (*1*). In the chick REM sleep comprises no

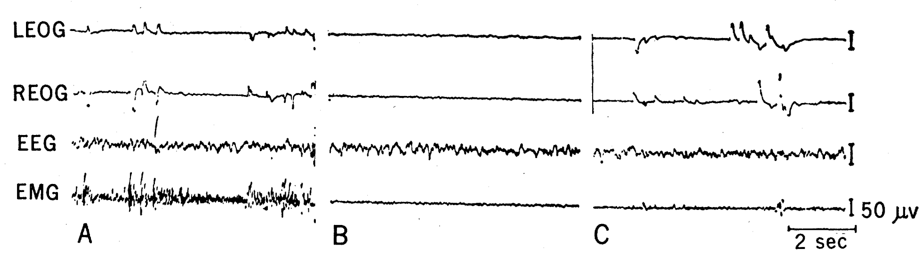

Fig. 1. Recordings showing (A) wakefulness, (B) N-REM sleep, (C) REM sleep; *LEOG*, left eye; *REOG*, right eye; *EEG*, forebrain; *EMG*, electromyogram of neck muscles.

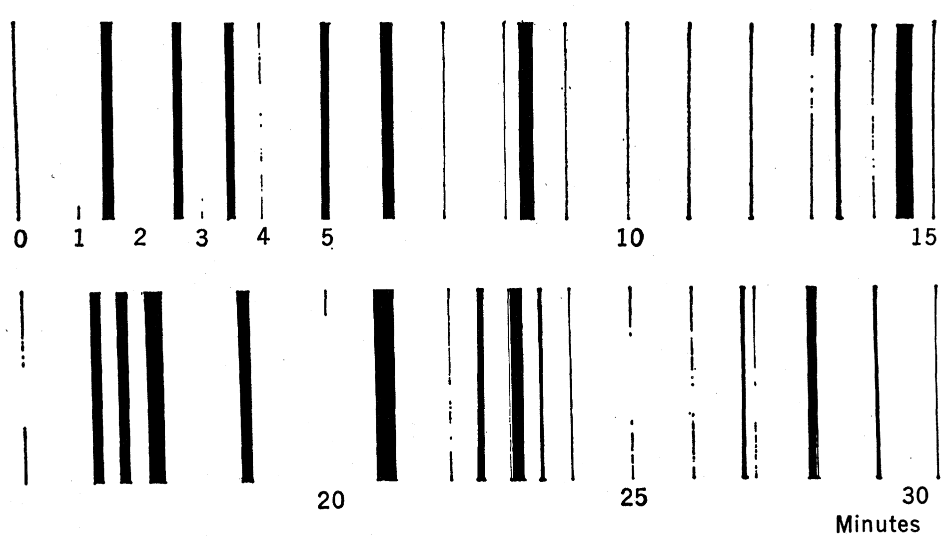

Fig. 2. Rapid eye movement (REM) during sleep in avian predators. Dark stripes represent duration in seconds of a REM burst over a period of 30 minutes. The REM bursts averaged 7 to 10 percent of total sleep time. Figure was taken from a 5 a.m. recording and is a representative sample.