ruption (Fig. 1). Addition of acetylcholine ($1 \cdot 10^{-5}$ g/ml) to the perfusion fluid caused a decrease in the force of isometric contraction of strips of the right atrium (Fig. 2). It is interesting to note that the phenomena observed in the experiments on strips of atria of the experimental animals (Fig. 3) were similar to those obtained on strips of the right atrium of human autopsy material.

In view of generally accepted observations [1, 3, 5, 6, 7, 9] that catecholamines exert their effects on myocardial energetics and contraction through adenyl cyclase and the enzyme systems stimulating it, together with the results of the present experiments, it can be tentatively suggested that the functioning of this system in the myocardium persists during the post mortem period studied. The possibility of using autopsy material to obtain biochemical, biophysical, and physiological mechanisms lying at the basis of contraction of the human heart thus cannot be ruled out.

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CORRELATION BETWEEN EEG RHYTHMS AND GASTRIC CONTRACTIONS IN DOGS DURING PHYSIOLOGICAL HUNGER

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Among the ultradian rhythms a rhythm with cycles of 90-120 min, shared by periodic synchronous changes in many physiological functions (blood pressure, respiration rate, cardiac frequency, etc), can be distinguished. One of its clearest manifestations is the rhythm of periodic activity (PA) of the organs of the digestive tract under conditions of physiological hunger. Combined cyclic changes in the secretory and motor functions of organs of the gastrointestinal tract and in other physiological functions suggested that PA may exist in the body in cases other than digestion [2]. Recording PA and behavior of dogs every 5 min in the course of experiments lasting several hours, whether by day or by night, has shown that synchronous changes in the functional state of the CNS are an invariable component of PA. They are expressed as regular changes in the depth of sleep or as awakening of the dogs before the beginning of the next period of gastric activity, and sometimes again immediately after a period of such activity [2, 3].

It was accordingly decided to study possible correlations between CNS rhythms and PA of the gastrointestinal tract, and the investigation described below was undertaken for this purpose.

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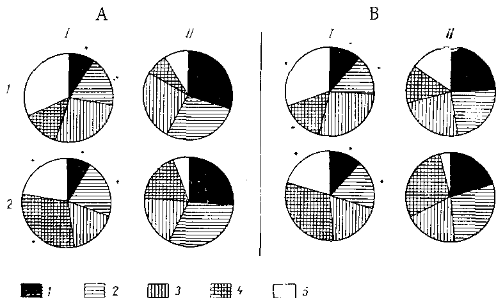

Fig. 1. Contribution of waves of different frequencies (in % of total EEG activity) in different phases of cycles of gastric periodic activity. A) Dog No. 1; B) dog No. 2; I and II) periods of gastric contractions and of rest, respectively; 1-5) frequency bands (in % of total activity). Derivations 1 and 2 of EEG from projections of orbital and motor areas of the brain. *) Differences between values at rest and during contractions significant at the $P < 0.05$ level between I and II.

EXPERIMENTAL METHOD

Chronic experiments were carried out in the course of the year on two mongrel male dogs with Basov's fistulas of the fundal part of the stomach. Bipolar silver wire electrodes 0.2 mm in diameter in polyethylene insulation were inserted into the cranial bones symmetrically, at points corresponding to projections of the visual, auditory, motor, and orbital (conventionally) areas of the cortex, by the method and with the direct assistance of N. N. Lyubimov (Brain Institute, Academy of Medical Sciences of the USSR). All preparatory operations were performed 2-3 months before the experiments began.

The experiments were conducted in an insulated, screened chamber with weak artificial illumination. The recording systems and the experimenter were in an adjoining room. To begin with the dogs were familiarized with the experimental situation. The animals were fixed by a collar with a short lead to the stand of an ordinary frame on which they lay, and they could stand up and sit down. Indicators of the end of adaptation were regular gastric PA and quiet behavior of the dogs on the frame. Throughout the experiments the dogs mostly lay quietly and dozed, changing their position occasionally.

Periodic gastric contractions were recorded by a balloon-graphic method. Respiratory movements and changes in the dog's behavior, accompanied by changes in the intragastric pressure, were recorded simultaneously on the drum of a chymograph, thus providing a type of "actogram." The EEG was recorded on an ME-171-D encephalograph (Nihon Kohden, Japan), equipped with a type MAF-4 automatic frequency analyzer, by means of which synchronous spectral analysis of the EEG could be carried out in two chosen channels in the following five frequency bands: 2-4 Hz (1st), 4-8 Hz (2nd), 8-12 Hz (3rd), 13-20 Hz (4th), and 20-30 Hz (5th). (The frequency bands are given below under the appropriate numbers.) At least three EEGs were recorded during each rest period and two or three EEGs in periods of gastric contractions, each consisting of four or five 10-sec epochs. The ratio of the squares of amplitudes of each component frequency, with respect to fixed indicator readings, to the sum of the squares of all frequencies in the given epoch, was calculated for each epoch. The results were then averaged for all epochs of the given EEG and the mean value was then calculated both from aggregated data for each phase of the cycles and separately for five points during periods of work and rest (see Fig. 3). The results were subjected to statistical analysis [1]. The samples for each dog and for each derivation separately consisted of 10 (during the dynamic analysis) to 30 experiments.

The experiments were carried out mainly during the afternoon and evening, 18-20 h after the animals' last meal, when the secretion obtained from the stomach with the gastric fistulas closed was alkaline.

EXPERIMENTAL RESULTS

Gastric PA of each dog was characterized by the following stable parameters: The mean duration of the cycles was 105 ± 15 min, of the periods of work 25 ± 5 min, and of the rest periods 80 ± 10 min. In an experiment lasting 5-9 h, three to five or more cycles were recorded.

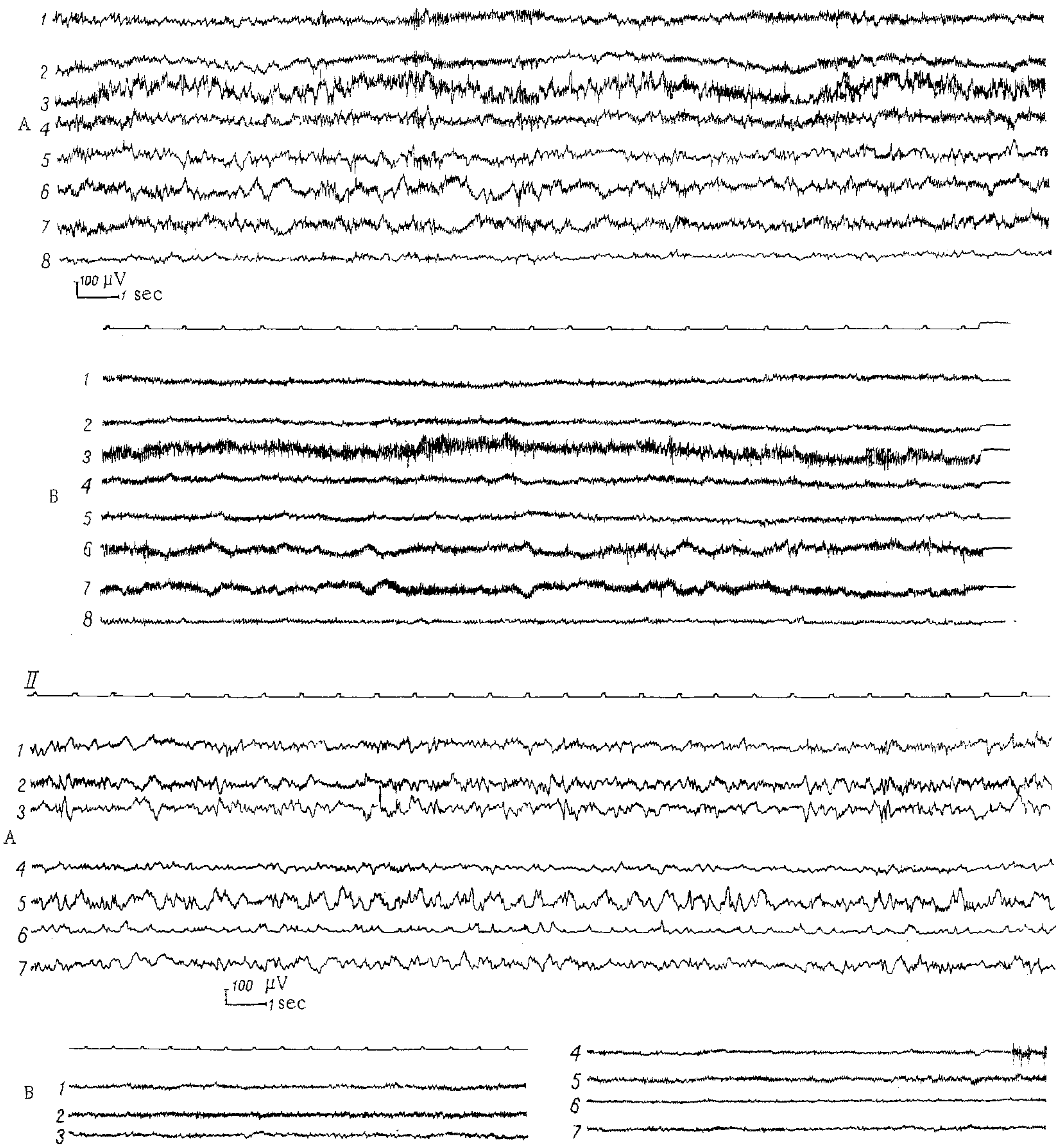

Fig. 2. EEG of dogs in periods of rest (A) and gastric contractions (B). I) Dog No. 2; II) dog No. 1. 1-8) Channels of recording; L) left hemisphere; R) right hemisphere; M) derivation from projection of motor, O) orbital, A) auditory, V) visual area. Channels (in dog No. 2): 1) RM, 2) LM, 3) RO, 4) LO, 5) LA, 6) RV, 7) LV, 8) (R − L)V; dog. No. 1): 1) LM, 2) RM, 3) RO, 4) RV, 5) LV, 6) LA, 7) LO. Vertical scale 1 cm = 100 μV, horizontal scale 3 cm ≈ 1 sec.

The spectral characteristics of the component rhythms of the EEG changed regularly corresponding to each phase of the cycles. In the rest periods the contribution of slow components increased significantly compared with their contribution during work in each of the dogs (bands 1 and 2, corresponding to waves of the δ_1 and θ types). Conversely, the relative contribution of the fast component of the EEG to total electrical activity of the brain in band 5, corresponding to waves of the β_2 type, was significantly higher during work and it fell in the periods of gastric rest.

This rule was observed in all derivations analyzed (1 and 2, corresponding to projections of the orbital and motor areas), with only small individual differences for each dog (Fig. 1). In the periods of gastric contractions this combined contribution of waves of frequency bands 1 and 2 to the total activity was about 28%, that of bands 3 and 4 was 45-50%, and that of band 5 was on average about 25%. With the onset of rest periods a clear redistribution of the contributions of the corresponding frequencies to total brain electrical activity took place: The combined contribution of waves of bands 1 and 2 was doubled to 48-57% and the contribution of

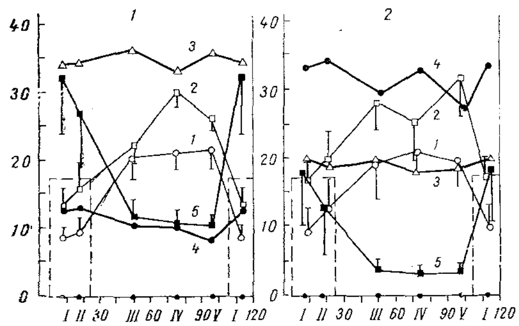

Fig. 3. Dynamics of changes in EEG frequency spectrum during cycle of gastric PA (dog. No. 2). Frequency bands represented by graphs: 1) 2-4 Hz, 2) 4-8 Hz, 3) 8-12 Hz, 4) 12-20 Hz, 5) 20-30 Hz. 1, 2) EEG derivations from motor and orbital areas, respectively. Abscissa, time (in min), each marker 10 min; filled circles on abscissa indicate EEG summation points for phases of the cycles: I and II) during contractions III, IV, V) during rest period; ordinate, percentages (mean weighted coefficient) of each band relative to total brain electrical activity at the given moment. Dashed rectangles denote periods of gastric contractions: time scale along horizontal axis.

the fast component (band 5) fell sharply to 6-8%. The combined contribution of waves of bands 3 and 4 fell very slightly or was almost unchanged. During repetition of the cycles, the ratios between the EEG frequencies changed in exactly the same way. Consequently, during PA there were regular cyclic changes in the ratios between the various frequency bands composing total brain electrical activity.

Amplitude analysis of the EEG was not specially undertaken. It will be clear from the EEGs illustrated that during rest periods, against the background of predominance of slow waves (Fig. 2A), these waves also had a considerably higher amplitude than the fast waves during periods of work (Fig. 2B).

A more detailed analysis of the dynamics of changes in the mean weighted coefficients for two points in periods of work and three points in rest periods shed some light on the character of the transitions during each cycle. Since the dynamics of the process was virtually identical, the results obtained in experiments on dog No. 2 will be given (Fig. 3). As Fig. 3 shows, the contributions of frequency bands 1 and 2 were minimal at the beginning of work periods and their increase or decrease towards its end was not significant. Toward the middle of the rest periods the contribution of each frequency band to the total EEG rose sharply, but toward the beginning of the next period of work it fell. In the course of the changes in the rapid component the stepwise character of the transitions was even more marked, although it is possible that the dynamics could be rather different had a larger number of points of analysis been taken. Figure 3 also shows the relative constancy of the combined contribution of waves of bands 3 and 4 to total activity regardless of the phase of the cycles (for that reason, the ranges of variations of the means for these frequencies are not indicated). The combined percentage of these frequency bands, it will be noted, remained constant because when the contribution of band 3 was high, that of band 4 was relatively low, and vice versa (Fig. 3: 1, 2). The dynamics of changes in the contribution of the fast and slow components of the EEG was constant irrespective of whether band 3 predominated over band 4 (Fig. 3: 1) or vice versa (Fig. 3: 2).

Cyclic changes in the frequency spectrum of total brain electrical activity reflected in the EEG, synchronous with gastric PA, are thus a regular feature and just as stereotyped as the PA itself. During deviations of PA from the stereotypes, which were sometimes observed in the experiments, the relationships were different, but this problem deserves special examination. There is no doubt that the changes found in the EEG frequency spectrum were connected with changes in the dogs' behavior observed visually by V. N. Boldyrev and many other workers during prolonged recording of PA, i.e., with the phases of sleep and transitions from

TABLE 1. Mean Weighted Coefficients of EEG Frequency Bands during Periods of Gastric Contractions, Differentiated depending on Contracted or Relaxed State of the Stomach ($M \pm \sigma$)

Frequency bands	Dog No. 1		Dog No. 2	
	during contraction	during pause	during contraction	during pause
1	8,7±3,8 (6,2—11,2)	11,8±2,6 (8,7—14,9)	11,0±2,4 (8,6—13,4)	9,5±1,2 (8,2—10,7)
2	16,9±3,8 (14,4—19,2)	16,4±3,9 (11,8—21,0)	16,3±2,5 (13,9—18,7)	14,8±2,0 (12,8—16,8)
3	29,5±5,6 (25,6—33,2)	34,4±5,2 (28,3—40,5)	27,2±2,4 (24,8±29,6)	27,1±1,6 (25,5—28,7)
4	14,1±2,5 (12,4—15,8)	14,8±3,5 (10,7±18,9)	17,0±2,0 (15,0—18,0)	17,3±1,6 (15,7—18,9)
5	31,1±8,8 (25,2—37,0)	22,8±7,8 (13,6—32,0)	30,0±3,6 (26,4—33,6)	31,4±4,0 (27,3—35,3)

Legend. Dog. No. 1 – derivation 1, projection of motor area; dog No. 2 – derivation 2, projection of orbital (conventionally) area; range of variations for 95% confidence interval given in parentheses.

sleep to quiet wakefulness. Since clear changes in the EEG were found in derivations from anterior brain zones (projections of the orbital and motor areas) it was logical to suggest that the flow of interoceptive impulses from the contracting stomach, intensified in periods of work, may act as a sufficiently powerful stimulus to reduce the depth of sleep or the transitions from sleep to temporary quiet wakefulness.

For the preliminary verification of this hypothesis EEGs recorded during periods of work were subjected to separate analysis. Since each contraction in periods of work and the pauses between them lasted about 1 min (rhythm 1, contraction once every 2 min), the EEGs were recorded either during contraction or during the pauses between contractions. This comparative analysis revealed virtually no significant differences (Table 1).

Besides gastric contractions, other sources of interoceptive impulsation may be periodic contractions of the duodenum and proximal end of the jejunum, which are known to be synchronized with periods of work of the stomach, periodic secretions, and so on. Accordingly this problem, and also the "strength" of the correlation found outside the limits of the PA stereotype during physiological hunger, its direct mechanisms, and the possibility of its use under pathological conditions all call for further study.

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