

Biological Cycles and Rhythms Vs. Biorhythms

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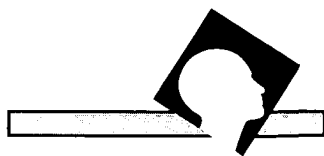
Biological cycles are an exciting frontier in current research. We now understand biological cycles and rhythms quite well. However, there is still much to discover.

The word *biorhythms* sounds much like “biological rhythms.” Some may think it is just a shorter version with the same meaning. Indeed, an entry in the card index in my local library gives the direction: “Biorhythms. . . . See Biological Rhythms.” Biorhythms are the fixed 23-, 28-, 33-day cycles said by some to pervade all life—the supposed cyclic variations in the physical (male), emotional (female, sensitivity), and intellectual attributes that determine the daily fluctuations in our moods, interests, abilities, and accident susceptibility.

So where do biorhythms fit into our knowledge of biological cycles and rhythms? Are they synonymous? Are biorhythms a real part of biological science or just a pseudoscience of no value? I will give the general characteristics of biological cycles and rhythms and describe some typical ones to suggest how physiologists approach, study, and understand them. A comparison of physiologically based biological cycles and rhythms with biorhythms shows that biorhythms are, to say the least, in a class apart.

Cycles and Rhythms

The difference between “cycles” and “rhythms” is more than just etymological; the distinction is real and useful. A “cycle” is an endless series, a repeating sequence of events, where each event is the consequence of the preceding events



Biological cycles and rhythms are well established. Where do 'biorhythms' fit in?

and the cause of the succeeding events (like the rotating wheel, or cycle).

One biological cycle is the electrical activity of the sino-atrial node of our hearts. Sodium ions (Na^+) diffuse into the cardiac cell, and potassium ions (K^+) diffuse out through pores in the leaky cell membrane.¹ This migration reduces the normal degree of electrical polarization across the cell membrane from -70 millivolts (mV). When this polarization has "decayed" to -60 mV, depolarization is triggered. This is the rapid free diffusion of sodium ions into the cell (potassium, chloride, and calcium ions are involved too), with the result that the electrical potential falls rapidly to zero and overshoots beyond to -60 mV.

This loss of the electrical polarization of the cell membrane triggers the free diffusion of ions through the adjacent areas of the heart cell membrane, the consequent loss of electrical polarization in that area, and the same sequence of events in progressively further adjacent areas. And so the wave of ionic diffusion and electrical depolarization, a self-sustaining action potential, propagates through the cell membrane throughout the heart, triggering muscle contraction as it passes.

Meanwhile, back at the sino-atrial node, the cell membrane resumes restricting the diffusion of the Na^+ and K^+ , and complex proteins embedded in the membrane sequentially attract Na^+ and K^+ , move the ions across the membrane, and release them, thereby pumping the Na^+ back outside the cell and the K^+ in. This is the energy-consuming sodium-potassium pump, and the ionic imbalance it produces regenerates the electrical polarization of -70 mV inside the cell.

No sooner have the Na^+ and K^+ concentrations been restored than diffusion through the membrane pores

resumes, and the electrical polarization again decays. This is the cycle of activity within the sino-atrial node. Each event in the sequence is the consequence of the preceding events and, in turn, causes the succeeding events.

We can readily monitor the sino-atrial node cycle in an experimental animal by recording the aggregate electrical de- and re-polarizations of the cell membranes. With somewhat more effort we can measure the changing electrical potential across the membrane of individual sino-atrial node cells, or the influx and eflux of sodium and potassium ions.

"Rhythms," on the other hand, are series of events. Each event is caused by a preceding event, but each series does *not* cause the succeeding series. Often obvious rhythms are being triggered by inconspicuous cycles.

The muscle in the atria and ventricles of the heart display rhythmic activity. Each receives a wave of membrane depolarization (an action potential) originating in the cyclic activity of the sino-atrial node. This causes the cell membranes to depolarize, calcium ions to flow, and muscles to contract. And this increases the pressure within each chamber and pumps the blood.

Each series of events within the atria and ventricles is triggered by the membrane depolarization that originates in the sino-atrial node; each series is relatively unaffected by preceding series and has little (if any) effect on succeeding series or the cyclic activity of the sino-atrial node. The sino-atrial node can be separated from the rest of the heart (an analogous experiment can easily be performed on the intact toad heart); the sino-atrial node continues its cyclic activity oblivious of the quiescent atria and ventricles (one ventricle in the toad). Another easy experiment in the toad

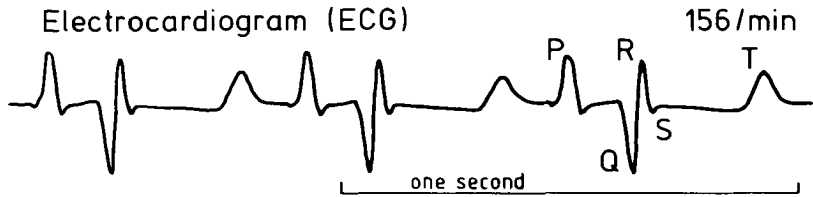


FIGURE 1: The Electrocardiogram. Electrodes placed on each of the four limbs and the chest allow the rhythmic net electrical activity of the heart to be recorded as the electrocardiogram (ECG). Since all the atrial cells depolarize synchronously and the ventricular cells depolarize and repolarize synchronously, the electrical changes generated are in phase and contribute to the identifiable net signals. (This is actually recorded in an anesthetized cat, hence the 156/minute, while the resting human heart rate is typically about 70/minute).

is to cool the sino-atrial node and slow its cyclic activity; consequently there is a greater interval between successive contractions of the ventricle. However, cooling the ventricle has no effect on the sino-atrial node's activity or the rhythm it generates; the ventricle continues to contract at the same rate. The cyclic activity of the sino-atrial node sets the rhythm for the whole heart; hence its popular name "the pacemaker."

Reasons and Causes (Why and How)

Biological cycles and rhythms are not random; they occur for a reason and have definite causes. The ventricles of the heart contract rhythmically to pump our blood; the cause of the contractions is the successive waves of membrane depolarization. Identifying the reason (the need for blood to be circulated) is important since this explains the timing of the immediate cause. The reason is the result of evolution; the cause, the result of biochemistry.

Sheep are sexually active in the autumn. The reason is that pregnancy lasts five months, and lambs must be born late enough for there to be sufficient grass to sustain the ewe through the nutritional demands of late pregnancy and lactation, yet early enough for the lamb to have sufficient

time for growth before the rigors of the next winter. Lambs will survive only if they are born as a result of a mating period of a few weeks in autumn; consequently, the sheep has evolved a restricted and carefully timed breeding season.

How does the sheep know what the conditions of the pastures will be in five months time? Fortunately plant growth is determined by the weather, and the seasonal changes in the weather are repetitive. The most reliable indicator of the time of the year, and therefore of the weather five or more months later, is the changing day-length.

The changing reproductive status of the sheep as the breeding season approaches can be observed. The increasing diameters of the ram's testes can be measured. Surgery on the ewe's ovaries reveals the growth of follicles and ovulation. Introducing the ram to the flock will identify the ewes in heat (estrus) as they stand to his mounting. (Nonestrous ewes are not attractive; and if the ram did try mounting, they would run away vigorously!)

The cause (the "how") of the sheep-breeding season is of great interest to scientists. Light stimulates nonvisual photoreceptors in the retina. The sensory nerves bypass the visual centers in the brain to trigger the

suprachiasmatic nuclei of the hypothalamus. Here action potentials are generated in sympathetic nerves that are routed down the spinal cord in the neck and back up to innervate and inhibit the pineal gland. A remnant of "the third eye" (it still exists in fish and amphibia)—René Descartes's "seat of our rational souls"—the pineal secretes a number of chemicals. Best understood so far is the association of darkness with the pineal's enzymes and its synthesis and secretion of the hormone melatonin. As well as blanching the skin of tadpoles, melatonin can stimulate or inhibit reproductive activity, depending on the species. During the lengthening nights of autumn the melatonin secreted in sheep during the hours of darkness decreases the negative feed-

back sensitivity of the hypothalamic-pituitary axis to gonadal steroids; consequently greater secretion of gonadotrophic hormones stimulates the ovaries and testes (in different animals) and the breeding season starts.

The pineal-melatonin system is one line of research that has had great success in recent years and is still being investigated. Both the reason (the coordination of the needs of the mother and the lamb for food with plant growth) and the cause (light, pineal melatonin, sensitivity to steroids) are well understood.

Biological Clocks

Many biological rhythms are triggered by environmental changes. The tim-

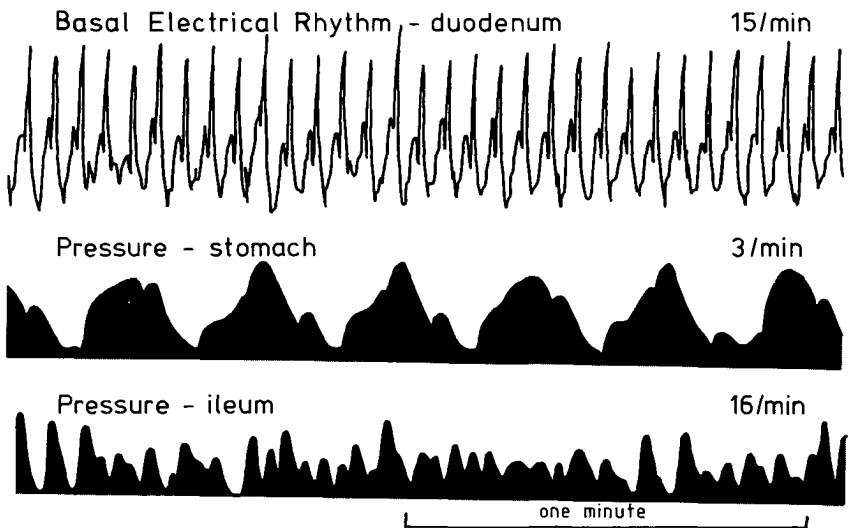


FIGURE 2: Electrical and Muscular Rhythms in the Gut. Fine wire electrodes sewn through the longitudinal muscle in the wall of the stomach or small intestine allow electrical activity to be recorded. This reveals the Basal Electrical Rhythm (BER)—a wave of partial depolarization of the muscle cell membranes that propagates through the gut (the top trace). In the stomach this rhythm originates in a "pacemaker" located at the entry of the esophagus, and in the small intestine one "pacemaker" is found near the entry of the bile duct into the duodenum with another two or three pacemakers further down in the jejunum and ileum. The BER oscillates at 3 cycles/minute in the stomach and 9 to 12 cycles/minute in the small intestine and propagates through the longitudinal muscle at 5 to 40 and 200 mm/second, respectively. (These are the figures for the human. This recording was made in an anesthetized cat, which may explain the greater frequency (15/minute) of the duodenal BER.)

Sheep breeding seasons

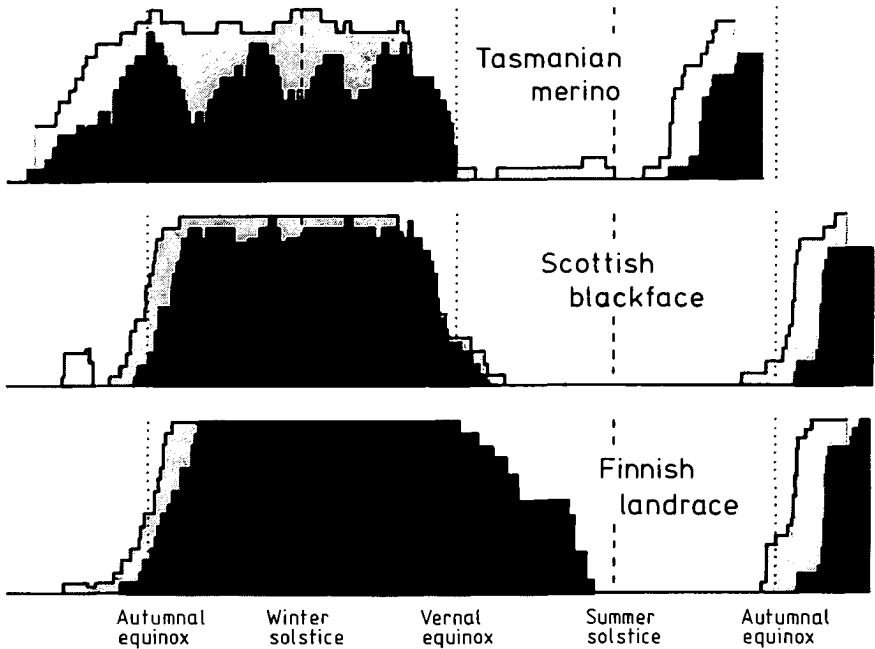


FIGURE 3: The Sheep Breeding Season. The timing of the onset of the sheep's breeding season is determined by the day-length. The breeding season consists of a series of ovarian cycles, each including waves of follicle growth, ovulation, luteal activity, luteal regression, and back to another wave of follicle growth. The ovarian cycle is controlled by ovarian steroid and gonadotrophic hormones. The ovarian follicular estrogen secreted in great quantities for the 12 hours before ovulation induces estrous activity. During estrus the ewe is attractive to the ram and will stand still to his mounting and intromission. Estrus synchronizes mating with ovulation, sex with fertility.

In natural conditions the ewe would conceive during her first or second estrus. However, by using vasectomized rams we can observe successive estrous activities throughout the year without our ewes' getting pregnant and ceasing cycling. This exposes the duration and end of the breeding season, normally masked by pregnancy and lactation.

The figure shows behavioral (estrus; light hatch) and ovarian activity (ovulation; dark hatch) during the year in three breeds of sheep in the same environment. The three breeds react differently to the same changing day-length, the Scottish blackface showing the "classic" short breeding season.

ing of the sheep's breeding season is determined by the decreasing day-length of autumn. But supplement the short days of winter with electric lights and abbreviate the long days of summer with light-proof blinds so as to maintain a constant "day"-length, and the sheep-breeding season will still start at about the right time. While the timing of our cycles and rhythms may be refined (entrainment) by clues

from our environment (the *zeitgeber*), taking those clues away reveals inherent "clocks." These biological clocks generally run a little slow, so that they initiate activity only if the normal environmental trigger is absent (sustained heavy cloud?).

In normal circumstances the activity of our body follows a rhythm appropriate to our changing needs. Our body temperature is lowest in the

morning and highest in the evening, urine production by the kidneys decreases at night, tiredness and fatigue come over us late in the evening, and so on. Remove all external clues to the passage of time by housing volunteers in insulated, isolated caves, and the same pattern of activity is still apparent, except with a slightly longer "day" of about 25 to 27 hours. (Many aspects of this variation, like body temperature in humans and activity in hamsters, are easily measurable.) This is the circadian rhythm.

Synchrony

Animals that live in shallow water need to anticipate high and low tides; their behavior describes a 12.4-hour circa-tidal rhythm. Animals living higher up the beach are interested in the timing of the highest (spring) and lowest (neap) high tides; their cycles are 14.8-days long (circa-semi-lunar). All the animals in these populations follow the same pattern of behavior at the same time; their cycles are synchronized.

In artificially constant conditions these animals cannot keep their cycles in step with their environmental trigger; the cycles "free-run" at 13 to 14 hours and 15 to 17 days, respectively. It is only in these conditions that the animals get out of step with each other and the population loses synchrony. The approximation of our inherent clocks is insufficient, our endogenous rhythms are only approximate, hence the "circa" ("about") in circadian rhythms. The remarkable synchrony in natural populations may be either coincidental (as in the feeding activity of the fiddler crab) or the purpose of the cycle (as in the swarming of the grunion fish on California beaches on the crest of spring high tides).

Manipulation

Take a jet plane on a trip east or west and you can rapidly cross several time zones. On arrival you adapt your behavior to the local pattern of activity: sleeping at the new nighttime, getting up in the new morning, working during the new day, seeking entertainment during the new evening, and so on. However, your body's physiology is still on home time; you feel sleepy in the day, energetic in the evening, and wide awake at night. This is "jet lag." This is to be expected; what is surprising is that within only five days your physiological rhythm adapts to your new behavioral rhythm.

Round up a flock of sheep in Britain and ship them to South America, and if you time it right they can have two breeding seasons within one calendar year. (This observation was one of the earliest clues to physiologists that the time of the sheep's breeding season is determined by the day-length.) Injecting or feeding melatonin to ewes in the autumn will retard the start of the breeding season.

Ride a bicycle vigorously and the parasympathetic nervous slowing of the sino-atrial node cycle will decrease, allowing your heart rate to increase from a typical 70 cycles per minute to about 100 per minute. With further exercise, sympathetic stimulation of the sino-atrial node will increase its cyclic activity and the heart rate will increase to more than 200 cycles per minute.

All the biological cycles and rhythms can be altered, or manipulated.

Biorhythms

Biorhythms are another matter entirely. Biorhythms are supposedly three cycles of absolutely fixed periods

(23, 28, and 33 days); each of the three biorhythms is said to "start" ascending from "0" at birth and continue unvaryingly until death. This is the same for everyone irrespective of style of "birth" (vaginal, planned [early] caesarian, or unexpected [late] caesarian) or the physiological status of the baby at birth (premature, early, term, or late). The history of biorhythms is described by Gardner (1966); why they supposedly start at "birth" is not explained.

Journey on a jet plane, work night shifts, volunteer for experiments into prolonged sleeplessness, or take drugs; nothing will change your biorhythms. Live in a constant, uniform environment with no clocks, under your endogenous 26-hour circadian rhythm, and your biorhythms will nevertheless continue at their 23, 28, and 33 24-hour "days." Biorhythms are presumably not easily

fooled; no environmental trigger, *zeitgeber*, or entrainment for them.

It is said you can measure the changing accident rate associated with biorhythms; or relate sudden deaths and sporting performance to biorhythms. These are the claims. On investigation the evidence has proved to be surprisingly ephemeral. Repeated studies have shown the claims fail (Bainbridge 1978; Hines 1979). We cannot measure these mysterious biorhythms. There is no biochemical, neurological, or physiological variable or correlate that can be monitored. As one popular book says: "Among our bodily rhythms are three clearly defined cycles that affect our behavior patterns but which have no cause and effect as such: They are simply continuous physiological changes" (West 1980:7). Biorhythms provide the physiologist with none of the usual electrical, mechanical,

Sex-skin prominence during Baboon menstrual cycles

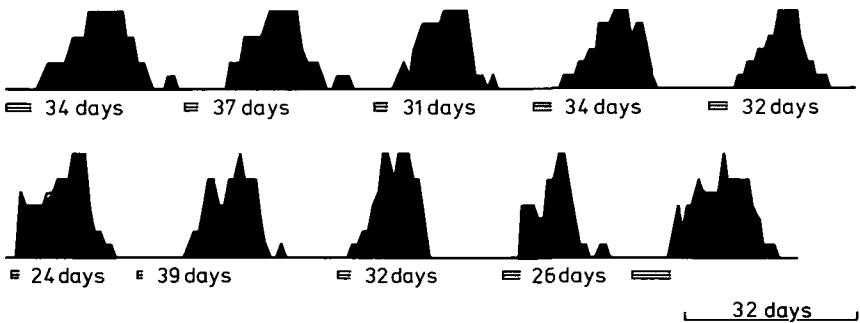


FIGURE 4: The Primate Menstrual Cycle. Cycles of ovarian activity in female nonpregnant primates produce sequentially estrogen and progesterone hormones that generate the changes associated with the menstrual cycle. Most obvious to humans is the blood lost at menstruation, though there are other aspects, such as edema (puffy swelling of the feet), tenderness of the breasts, and temperature changes. In the African baboon the estrogen secreted for two weeks by the growing follicles stimulates engorgement of the sex skin on the female's backside; the degree of engorgement and coloring (hatched areas) can be reliably subjectively assessed each morning. With ovulation the estrogen concentration decreases abruptly and the corpus luteum secretes progesterone for two weeks; these changes in turn cause an abrupt collapse and loss of color to the sex skin (defumescence). At the end of this period the corpus luteum regresses and the progesterone concentration falls; this stimulates menstruation (bars). The time between the start of one menstruation and the next is the length of the menstrual cycle; this averages about 32 days in the baboon.

hydraulic, or biochemical variables to record and analyze.

Biological cycles and rhythms are components of our complex and harmonious biology. Biorhythms, on the other hand, are unrelated to any other biological variable; they are apart and unconnected. Biorhythms are easy to explain and understand—but only because there are no physiological changes to explain, no physiological consequences to understand. Biological cycles and rhythms explain observations; periodic heart sounds, body temperature changes, menstruation, and so on, all make sense as components of a more basic rhythm. Biorhythms explain no such observations; there is no unexplained data in need of such a notion.

Note

1. Original references have not been provided for much of this information; otherwise the references would occupy more

space than the text. Most of this material is likely to be found in any textbook on physiology (for example, Arthur C. Guyton, *Textbook of Medical Physiology*. Philadelphia: W. B. Saunders, 1986).

References

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GREAT FRAUDS IN THE HISTORY OF MAGIC