Rhythms in Nature

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Rhythm

The dictionaries, both popular and technical, list many definitions for the word "rhythm." Most of these definitions are in the fields of art, speech, music, sound, march, cadence, and the like, but rhythms occur in nature also. A rhythm discussed in this issue of *The Kansas School Naturalist*, is a natural movement or change characterized by alternations or "ups and downs" that occur at more or less regular intervals. In technical books on articles such as the words rhythm often called "periodicity" or "periodism." The term "cycle" is used to denote a series of regularly recurring events or changes. In different science books these terms are used more or less as synonyms; it would be more confusing than enlightening to try to distinguish among them for our present purposes.

Rhythms are equally common and familiar in the physical (inanimate or non-living) world and the living world. In a broad sense the major changes occurring in the earth and solar system are rhythmic. No one knows how closely the various rhythms of the physical world are related to one another, or how closely the rhythms of living things are tied to those of the physical world. We have much conflicting evidence, for example about the influence of sunspot cycles on such other rhythms as seasonal rainfall variations, changes
Rhythms in Nature

John Breukelman

The dictionaries, both popular and technical, list many definitions for the word "rhythm." Most of these definitions are in the fields of speech, music, sound, marching cadence, and the like, but rhythms occur in nature also. A rhythm, as discussed in this issue of The Kansas School Naturalist, is a natural movement or change characterized by alternations or "ups and downs" that occur at more or less regular intervals. In technical books and articles such natural rhythm is often called "periodicity" or "periodism." The term "cycle" is also used to denote a series of regularly recurring events or changes. In different science books these terms are used more or less as synonyms; it would be more confusing than enlightening to try to distinguish among them for our present purposes.

Rhythms are equally common and familiar in the physical (inanimate or non-living) world and in the living world. In a broad sense, the major changes occurring in the earth and solar system are rhythmic. No one knows how closely the various rhythms of the physical world are related to one another, or how closely the rhythms of living things are tied to those of the physical world. We have much conflicting evidence, for example, about the influence of sun spot cycles on such other rhythms as annual rainfall variations, changes in atmospheric radioactivity, and changes in total solar energy that reaches the earth. These may in turn influence tree growth, bird migration, types and frequencies of human diseases, and other rhythmic changes in living things.

Some Rhythms in the Physical World

In the physical world we see light and dark alternating in a 24-hour rhythm, the progression of the seasons as the earth swings annually in its orbit about the sun, the precise cycle of new moon, first quarter, full moon, and last quarter as the moon travels around the earth once each lunar month, the much less precise daily variations in temperature and humidity, and the year-by-year changes in precipitation which are so irregular that many people think they should not even be called rhythms or cycles.

All of the foregoing are relatively rapid rhythms, and are therefore easy to see. But scientists have studied rhythmic changes taking place over thousands of years, such as the gradual changes in the climate of an area. These changes are not easily seen and are revealed only by careful and detailed research. Geological rhythms of sedimentation and erosion occur so slowly that millions of years may elapse in a single cycle. Space permits only one example of such long-
time rhythms; I have chosen the changing levels of the ocean. By studying the shorelines of the seas of previous geological periods, scientists are able to determine the earlier sea levels. It is also possible to estimate the time at which the shorelines existed at various levels. The types of sediment, the types of fossils, and measurements of radioactive carbon-14 provide estimates of the age of a shoreline. Some "drowned" beaches, about 17,000 years old, now lie as much as 100 meters, or 330 feet, below sea level. Or in other words, the sea level 17,000 years ago (at the height of the most recent period of glaciation) was about 100 meters lower than it is at present. As the glacial ice melted and the waters flowed into the sea, the sea level rose, at a varying rate, with an average rate of a little less than a half inch per year. Carbon-14 measurements show that this varying rate was rhythmic, sometimes at nearly two meters per year, while at other times the level actually dropped short periods. During the 6,000 years the levels of the sea have not been more than three or four meters, or 10 to 13 feet, above or below the present level, and fluctuations above and below the present average have been decreasing. Figure 1 shows the gradual rise in sea level from 17,000 years ago to 6,000 years ago and the fluctuating sea level since then, the average for the 6,000 years being about the same as the present level.

Precipitation

The term "precipitation" is ordinarily used to include all forms of water falling from the atmosphere to the land—rain, snow, sleet, or hail. In Kansas, as in most of the United States, nearly all precipitation is in the form of rain or snow. Since the amount of rain and snow that falls during the year is an important item in Kansas, let us examine some of its rhythmic aspects. One of the obvious rhythms is that of the mean (average) monthly precipitation. Figure 2 shows the monthly averages for the entire state, through the 74-year period from 1887 to 1960.

January is the month of low precipitation, with a 74-year average of less than an inch. Monthly precipitation increases regularly until June, the month of great precipitation in most years, with an average of more than four inches. The average amount of rainfall drops almost an inch from June to July, remains about the same until August, then drops regularly
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January is the month of lowest precipitation, with a 74-year average of less than an inch. Monthly precipitation increases regularly until June, the month of greatest precipitation in most years, with an average of more than four inches. The average amount of rainfall drops almost an inch from June to July, remains about the same in August, then drops regularly to December, which also has an average of less than an inch, but not quite so low as January. From the standpoint of agriculture, this annual rhythm in amount of precipitation is favorable. More than three-fourths of the total precipitation for the year falls during the six crop-growing months from April to September.

This rather clear cut pattern is only an average, however. Much variation exists from one year to another, even though the overall pattern remains about the same. Figure 3 shows the monthly precipitation for the extremely dry year of 1956, the average year of 1947, and the extremely wet year of 1951. It will be noted that the highest precipitation in each of the three years came in June or July and the lowest during the winter. But the figure for June, 1951 (9.55
Figure 3. The rhythmic pattern of annual precipitation is similar for the three years, but the details vary greatly. In the high month of June 1951 Kansas received nearly two thirds as much precipitation as it did in the entire year of 1956.

Kansas is a large state, about 400 miles from east to west and about 200 miles from north to south, with an average of more than 40 inches of precipitation annually in the southeast and less than 20 inches along the western border. The geographical variation, although not as striking as the year-to-year variation, is considerable. Figure 4 shows the monthly precipitations as recorded in six different localities. Here, as in Figure 3, the overall pattern in all six localities is about the same.

inches) is more than three times that for July, 1956 (3.16 inches). During these three years the average precipitation figures for the whole state were 15.39, 26.85, and 41.58 respectively. The 74-year average for the state is 26.76 inches.

While the average for 1947 (26.85) was extremely close to the 74-year average, the month by month figures show considerable variation. That is, the year 1947 was an average one, but not all months were average, as shown in the table below.

Monthly precipitation in 1947 compared with average monthly precipitation in Kansas

<table>
<thead>
<tr>
<th>Month</th>
<th>1947</th>
<th>74-year average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>0.57</td>
<td>0.70</td>
</tr>
<tr>
<td>Feb.</td>
<td>0.46</td>
<td>0.99</td>
</tr>
<tr>
<td>Mar.</td>
<td>2.28</td>
<td>1.53</td>
</tr>
<tr>
<td>Apr.</td>
<td>4.52</td>
<td>2.58</td>
</tr>
<tr>
<td>May</td>
<td>4.58</td>
<td>3.87</td>
</tr>
<tr>
<td>June</td>
<td>4.89</td>
<td>4.05</td>
</tr>
<tr>
<td>July</td>
<td>2.04</td>
<td>3.27</td>
</tr>
<tr>
<td>Aug.</td>
<td>1.90</td>
<td>3.07</td>
</tr>
<tr>
<td>Sept.</td>
<td>1.27</td>
<td>2.75</td>
</tr>
<tr>
<td>Oct.</td>
<td>1.15</td>
<td>1.91</td>
</tr>
<tr>
<td>Nov.</td>
<td>1.18</td>
<td>1.20</td>
</tr>
<tr>
<td>Dec.</td>
<td>2.01</td>
<td>0.84</td>
</tr>
<tr>
<td>Total</td>
<td>26.85</td>
<td>26.76</td>
</tr>
</tbody>
</table>

When we examine the ups and downs in yearly precipitation in any one locality we see a most irregular rhythm. In Figure 5, the solid line shows the annual precipitation at Emporia from 1881 to 1960. The horizontal line indicates the 80-year average of about 34 inches. The all-time high of 59.56 inches in 1951 was almost twice the average, while the low of 11.80 inches during the drought of 1936 was only slightly more than one-half of the average. The time high was more than twice the all-time low. It is difficult at first to see any kind of pattern in this 80-year record but a close examination will reveal that there have been periods of successive years, such as 1917 to 1921, when totals were below average, and several others, such as 1944 to 1949, when they were well above average. A general view is possible when several successive years are averaged and plotted on a graph, rather than plotting each year individually. This tends to smooth out the irregularity of the pattern, and also reveals that rhythms exist, as shown by the broken line in Figure 5. The average annual precipitations were calculated for each successive five-year period.

Figure 4. The patterns of annual precipitation are similar for all six counties but the July-August drop followed by a September rise, so characteristic of the eastern counties (Brown, Cherokee, and Lyon), does not occur in the more westerly counties (Ellis, Greeley, and Pratt).

Figure 5. The 80-year record of precipitation at Emporia from 1881 to 1960. The solid line shows the annual precipitation, the horizontal line indicates the 80-year average of about 34 inches.
Kansas is a large state, about 400 miles from east to west and about 20 inches in the western border. The geographical variation, although not as striking as the year-to-year variation, is considerable. Figure 4 shows the monthly precipitations recorded in six different localities. Here, as in Figure 3, the overall pattern in all six localities is the same.

When we examine the ups and downs in yearly precipitation in one locality, we see a most irregular rhythm. In Figure 5, the line shows the annual precipitation at Emporia from 1881 to 1950. The horizontal line indicates the 50-year average of about 34 inches. The all-time high of 57.56 inches in the great flood year of 1951 was about 70 per cent above average, while the low of 18.13 inches during the drought of the 30's (1936) was only slightly more than one-half of the average. The all-time high was more than three times the all-time low. It is difficult at first to see any kind of pattern in this 80-year record but a closer look will reveal that there have been periods of successive years, such as 1917 to 1921, when totals were well below average, and several others, such as 1944 to 1949, when they were well above average. A more general view is possible when several successive years are averaged and plotted on a graph, rather than plotting each year individually. This tends to smooth out the irregularity of the pattern, and also reveals that rhythms exist, as shown by the broken line in Figure 5. For the broken line the average annual precipitations were calculated for each successive five-year period.

**Temperature and Humidity**

It is well-known that the outdoor temperature usually rises during the day and falls during the night. It is not so well-known that relative humidity changes are just the reverse; relative humidity usually rises during the night and falls during the day.

The relative humidity is the percentage of water vapor in the air, as compared with the amount that could be present at the temperature involved. The water vapor capacity of the air goes up and down with the temperature. For example, at ordinary atmospheric pressure a cubic meter of air at 10 degrees Centigrade can hold 9.33 grams of water, at 15 C, 12.71 grams, at 20 C, 17.12 grams, and at 25 C, 22.80 grams.

When the air warms up and the actual water content stays the same, the relative humidity falls. Thus a cubic meter of air which contains all the water possible at
10 C (9.33 grams) has a relative humidity of 100 per cent. If this cubic meter of air is warmed to 15 C, its capacity is 12.71 grams, but it still contains only 9.33 grams. The relative humidity is now 9.33/12.71 or 73 per cent.

When the air cools, the relative humidity rises; if it reaches 100 per cent of the water vapor capacity the air is said to be saturated. The temperature at which the air is saturated is often referred to as the dew point. If the temperature falls below the dew point some of the water vapor condenses as fog, mist, rain, snow, or sleet. Thus a cubic meter of air which contains 17.12 grams of water at 20 C is saturated, and the dew point is 20 C. If this air is cooled to 10 C, the water capacity is only 9.33 grams. The difference between 17.12 and 9.33, or 7.79 grams, is condensed as some form of precipitation.

If both temperature and relative humidity are recorded on the same strip of moving paper, a "mirror image" is drawn, as shown in Figure 6. The record shown was made by the instrument known as a recording hygrothermograph, located in the weather station at the Ross Natural History Reservation (The Kansas School Naturalist, Volume 7, Number 4, May 1961).

Temperature may be averaged by months and plotted by years. Figure 7 shows the average monthly temperatures in Kansas for the five-year period from 1936 to 1940. It will be noted that the pattern remains about the same, although the averages for the months change from year to year.

Wind

Wind velocities tend to increase during the afternoon and decrease during the evening and through the day period in September 1961 at the Ross Natural History Reservation; the relative humidity reached 100 per cent.

If there is any connection? The annual air temperature and relative humidity were drawn by Dr. Robert Boles, Assistant Professor of Biology, Kansas Teachers College; Mary Jones, a Superior Student, financed by the 1861 Summer Science Program Superior Students.
Did you think there is any connection? The annual averages are shown by the horizontal line. The average for the entire period was 7.04.

Figure 6. Variations in temperature (upper line) and relative humidity (lower line) during a six-day period in September 1961 at the Ross Natural History Reservation; during this period the relative humidity reached 100 per cent each night.

The graphs and diagrams in this issue were drawn by Dr. Robert Boles, Assistant Professor of Biology, Kansas State Teachers College; Mary Jones, Johnson High School, Johnson, Kansas, student in the 1961 Summer Science Program for Superior Students, financed by the National Science Foundation; and Teresa Duggan, Wichita, Kansas, freshman assistant in the Department of Biology, KSTC. Miss Jones and Miss Duggan worked under the supervision of Dr. Boles.
night. A characteristic daily wind velocity pattern is shown in Figure 8. Note that the August wind velocity is considerably higher than that for March, but that the patterns for the two months are quite similar.

Averages for all the months of the year also show characteristic annual rhythms. Figure 9 shows three annual average wind velocity patterns, for three widely separated areas in Kansas, for the period from 1932-1945. The overall patterns are similar, but some differences are obvious. The annual average wind velocity was much higher at Dodge City (12.9 miles per hour) than at Concordia (8.5), with Kansas City (10.1) between the two. The high-

**Figure 7.** Kansas temperature records show pronounced summer and winter extremes, with considerable variation from year to year, but in a constant overall pattern.

**Figure 8.** During the period 1902 to 1930 the lowest hourly wind velocity in Topeka in March was as high as the highest hourly wind velocity in August.

**Figure 9.** For the period 1932 to 1945, January and December low average velocities at Dodge City were above April wind velocities at Concordia as high as the high March wind velocities at Kansas City.

**Figure 10.** The difference between high moon and low moon are in line with each other, high and low moon velocities are at right angles.
The overall patterns are clear, but some differences are noted. The annual average wind velocity was much higher at Dodge (12.9 miles per hour) than at Concordia (8.5), with Kansas City an average in between the two. The highest average velocities came in April at Dodge City and Concordia, but in March at Kansas City.

**Tidal Rhythms**

Although we are not aware of them in Kansas, people who live near the seashore adjust many of their activities to the tidal rhythms—two high tides per day, about 12½ hours apart. They have also noticed that the moon has much more to do with tides than the sun. As the moon rises about 50 minutes later each day, so is each high tide about 50 minutes later than it was the day before. The monthly tidal cycle also matches that of the moon. Twice each month, when the moon is new and when it is full, the difference between high tide and low tide is greatest. This is called the spring tide. Likewise, when the
moon is at first and last quarter, the difference between high and low tide is the least. This is called the neap tide. At spring tide the sun, moon, and earth are in line; the sun and moon "pull together." At neap tide the sun and moon "pull" at right angles to each other. (Figure 10)

SOME RHYTHMS IN THE LIVING WORLD

Rhythms are as common in the living world as in the sun, plants, and earth. The daily and seasonal changes in light, atmospheric pressure, temperature, humidity, and other environmental factors are rather pronounced in all environments except deep water, the deeper layers of soil, and the larger and deeper caves. Most plants and animals live in environments with rhythmic changes, and they make daily or seasonal adjustments to the changing surroundings. Familiar examples are the butterflies, most of which are active by day, and the closely related moths, most of which are active by night. Seasonally, catbirds come from the south to nest in Kansas during the summer while Harris' sparrows come from the north to spend the winter in Kansas.

Many animals are active during certain parts of the day and rest other times. Although it is not generally known, many plants also have "sleep movements." These are too slow to see directly, but may be detected by examining plants at intervals by day and by night, or recorded photographically. Day and night positions are shown in Figure 11.

Heart Beat

One of the most familiar of all the rhythms of life is that of the beating of the heart. Each of us can be aware of this rhythm by feeling his own pulse. The heart beat is not merely contraction and relaxation of a single muscle. Contraction starts in a little islet of special tissue in the right auricle and passes wavelike over the entire heart. Complicated electrical changes accompany each heart beat. With suitable instruments these electrical changes can be recorded on a moving strip of paper. The instrument ordinarily used for clinical and research purposes is an electrocardiograph and the record produced by the instrument is an electrocardiogram. Figure 12 shows an electrocardiogram of a normal beating heart. The P wave records the contraction of the auricles, the QRS complex shows various stages in the contraction of the ventricles and the T wave records the relaxation of the ventricles. The time elapsed during one entire heart beat can be determined from the scale on the paper, each horizontal space representing one twentieth of a second.

Activity Rhythms

Individuals of many species show rhythmic activity. The periods of alternation vary greatly. A single cycle may take place in less than a second, as a heart beat may last many years, as the cycle of the periodical cicada (See page 14). Examples of time and daily rhythms are shown in Figure 13. The white-footed mouse is active during the day and rest at night. Eugene P. Odum, W. B. Saunders Comp
Night positions of leaves, redrawn from photographs by C. L. Wilson and W. E. Loomis, Press.

Beat

One of the most familiar of all rhythms of life is that of the heart. Each of us can feel this rhythm by feeling our pulse. The heart beat is not a true contraction and relaxation of a single muscle. Contraction and relaxation of a little islet of special tissue, the heart muscle, are carried on throughout the entire heart.

The heart generates electrical changes across each heart beat. With instruments these electrical changes can be recorded on a strip of paper. The instrument used for clinical search purposes is an electrocardiogram and the record produced by the instrument is an electrocardiogram. Figure 12 shows an electrocardiogram of a normal heart. The P wave records the contraction of the auricles, the QRS complex shows various stages of contraction of the ventricles, and the T wave records the relaxation of the ventricles. The time interval during one entire heart cycle can be determined from the scale on the paper, each horizontal space representing one twenty-fifth of a second.

Activity Rhythms

Individuals of many species show rhythmic activity. The periods of alternation vary greatly. A single cycle may take place in less than a second, as a heart beat, or may last many years, as the life cycle of the periodical cicadas. (See page 14.) Examples of short-time and daily rhythms are shown in Figure 13. The white-footed mouse is active at night and sleeps during the day. The rather similar pine vole is alternately quiet and active at intervals of an hour or less throughout the whole 24-hour period. The activity graphs were recorded automatically on a moving strip of paper, with the mice under controlled uniform conditions in a laboratory.

Grunions

One of the most interesting of the rhythms adjusted to the tides is that of the grunion, a small Pacific coast fish. This species "swarms" on the sandy beaches of California during the second, third, and fourth nights after the spring tide. The fish go on shore with the farthest advancing waves on the wet beach. The females wriggle into the moist sand and deposit eggs, over which the male ejaculates sperm cells as the eggs are deposited. The fertilized eggs are thus deposited in moist sand just at the highest wave level reached by the high tide, a level reached only at each spring tide. Although there are two high tides each day the fertilized eggs will not be washed away since the next high tides are too far apart.
not quite as high as the spring tide. The eggs hatch quickly and the developing young are not disturbed by waves until spring tide occurs, two weeks later; the young grunion are then washed out to sea. The grunion’s entire reproductive cycle is thus timed to fit the tidal rhythm.

Periodical Cicada

A striking example of a rhythm extending over several years is that of the periodical cicada, one species of which is commonly known as the 17-year locust. This insect is not a locust at all; locusts belong to the Order Orthoptera—grasshoppers, crickets, roaches, walking sticks, mantids, and katydids. The so-called 17-year “locust” is a species of the Order Homoptera—cicadas, leaf hoppers, aphids or plant lice, and scale insects. The adult (Figure 14) is slightly under two inches long. During “locust years” adults may be seen from May to August, this being the adult breeding season. The females deposit their eggs in twigs and stems of trees and shrubs. After about six weeks the eggs hatch and the young nymphs fall to the ground. They dig their way down to the roots of plants, especially trees and shrubs, pierce the roots and live on plant sap. After 16 summers underground, the fully-grown nymphs emerge during the 17th summer, crawl upon vegetation and become adults by a comparatively simple type of metamorphosis—directly from nymph to adult without a pupa stage. The last two “locust years” in Kansas were 1930 and 1947; the next two will be 1964 and 1981.

House Sparrow

Interesting breeding rhythms are shown by the house sparrow (often wrongly called the English sparrow). This species, found over most of the world, is a permanent resident active throughout the year. Being so widely distributed, house sparrows are adapted to a great variety of environments. Near the equator, where no winter occurs and seasonal variations are small, house sparrows breed throughout the year. In more northerly and southerly latitudes the breeding cycles are more pronounced as the distance from the equator increases. In Kansas, which is located between 37 and 40 north latitude, most of the breeding occurs during April, May and June. In the southern hemisphere, at a latitude equivalent to that of Kansas, most of the breeding occurs during September to December. These are spring and summer months south of the equator, where the seasons are the reverse of those with which we are familiar in the northern hemisphere. The South American summer comes during our winter, their fall during our spring. Figure 15 shows average breeding cycle house sparrows at 10-degree intervals north and south of the equator.

Population Rhythms

Populations of animals show annual rhythms, sometimes cycles which may extend over periods of years. One of the

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Figure 14. Dorsal view of the 17-year periodical cicada Magicicada septendecim, often incorrectly called the 17-year locust.

Figure 15. The annual cycles of breeding as the distance from the equator increases. Simpson, C. S. Pittendrigh, and L. H. Tinbergen, shows average breeding cycle house sparrows at 10-degree intervals north and south of the equator.
of plants, especially trees and shrubs, pierce the roots and live on them. After 16 summers under the fully-grown nymphs, during the 17th summer, upon vegetation and become by a comparatively simple of metamorphosis—directly nymph to adult without a stage. The last two "locusts" in Kansas were 1930 and the next two will be 1964 and 1980.

Sparrow
Breeding breeding rhythms are shown by the house sparrow (often called the English sparrow. This species, found over most of the northern hemisphere, is a permanent resident throughout the year. So widely distributed, house sparrows are adapted to a great variety of environments. Near the equator, where no winter occurs, seasonal variations are small, and breeding is continuous. In more northerly and southerly latitudes the breeding and migration patterns are more pronounced as the distance from the equator increases. This and Figure 15 were redrawn from Life, by G. G. Simpson, C. S. Pittendrigh, and L. H. Tiffany, Harcourt Brace and Company.

Figure 15. The annual cycles of breeding activity of the house sparrow are more pronounced as the distance from the equator increases. This and Figure 16 were redrawn from Life, by G. G. Simpson, C. S. Pittendrigh, and L. H. Tiffany, Harcourt Brace and Company.

Figure 16 shows average breeding cycles of house sparrows at 10-degree intervals north and south of the equator.

Population Rhythms
Populations of animals often show annual rhythms, sometimes in cycles which may extend over periods of years. One of the population cycles often mentioned as an example is that of the varying hare in Canada. Fur companies have kept records of the abundance of these animals since about 1750. Figure 16 shows a 75-year portion of such records. While this rhythm shows some irregularities, the peaks of abundance were reached at intervals of about 10 years, but the actual numbers during the highest peak year (more than 150,000 in 1863) were much higher than those of the lowest peak year (about 60,000 in 1904).

Figure 16. The eight "peaks" in the supply of hares occurred at intervals of about 10 years, but the actual numbers during the highest peak year (more than 150,000 in 1863) were much higher than those of the lowest peak year (about 60,000 in 1904).
about every ten years. The period from minimum population to maximum population averaged about five years.

Figure 17 (pages 8 and 9) shows the average number of different species of birds seen per day in the back yard of my home in Emporia, from 1953 to 1960 inclusive. The graph shows the same general pattern from year to year, with only minor variations. During the winter, relatively few different species are seen—house sparrow, robin, starling, cardinal, blue jay, downy woodpeckers, and chickadee being the most common—an average of about four or five different species per day. During the spring, as the migrating birds appear, the number increases abruptly, and then settles down to the summer residents, about eight to ten different species per day.

The month in which the largest average number of different species were seen was most often May, but it has also been June or August; the low month has usually been November, but January and February have also been low. The annual average has not varied much, as is shown by the horizontal line in Figure 17.

**Things to Do**

1. Make hourly, daily, weekly, or monthly temperature charts at home or at school, and plot these so as to show the changes over a chosen period of time.

2. Make a graph showing the changes in the length of the shadow of a selected fencepost, flag pole, or similar object from week to week. Be sure to make the measurements at the same time each day.

3. Keep a record of the number of different kinds of birds seen in the school yard each day or each week and make a graph to show the changes.

4. Compile weather records obtained from your own city or county over a period of several months and make suitable graphs. If you have a thermometer available you can make the temperature recording yourself. You can do the same with atmospheric pressure records if you have a barometer, relative humidity records if you have a hygrometer, and so on. Be sure to make the observations at comparable times each day.

5. Determine the times of sunrise and sunset either by your own observation or by looking them up in an almanac, calculate the day length and night length over a period of several weeks or months and make a graph showing the progressive changes in length of day and night.

6. From your county health office get records of the incidence of various diseases by weeks or months and make graphs showing annual variations.