In experiments involving the determination of the gas exchange of fishes it is necessary not only to handle them but to place them in an environment that is far from normal. As a result of this procedure, the respiratory metabolism is relatively high at first, but it gradually decreases with time. This initial high rate terminates usually, in from four to six hours. Most investigators (Gardner and Leetham, 1914; Ege and Krogh, 1916; Gaarder, 1918; Powers and Shipe, 1928; Hall, 1929, 1930; and others) have not taken into account this initial effect. Keys (1930) was the first to report it and he explained it as being due, in part at least, to the payment of an oxygen debt contracted by the fishes in their struggles incident to being placed in the respiratory apparatus, and possibly in part to sub-minimal stimuli (Winterstein and Hirschburger, 1927). He stated that "in order to be sure that the determinations represent standard or anything like basal metabolism, it is necessary to wait five or six hours after the fish has been placed in the apparatus before beginning the final determinations." He also assumed that if, after six hours in the respiratory chamber, two or more determinations over a minimum period of two hours checked reasonably well, they represented standard metabolism.

The purpose of the present paper is to attempt to show that, with Fundulus parvipinnis, even though there is a temporary equilibrium established five to six hours after the fishes have been installed in the respiratory chamber, this does not represent standard metabolism, but that after 24 hours or more a lower level is attained which is practically constant and represents "normal" metabolism.
In a long series of experiments carried out by the author to determine the effect of temperature on the rate of respiratory metabolism, it was found that this species, after a period of four to six hours in a respiratory chamber at a given temperature, usually strikes a metabolic level which it may maintain for several hours. It was many times noted, however, that the last determination indicated a lower level than any of the previous ones, which suggested that a normal level for the temperature in question had not been attained. In order to determine whether these frequent lower values were significant, a group of thirteen Fundulus which had been used a few days before were again placed in the respiratory chamber at the same temperature and kept there for one hundred hours. The values obtained from this and subsequent experiments will be set forth and discussed below. There were in all six series of oxygen determinations, each series representing a period of from 10 to 100 hours.

Material and Method.—The fishes used in the six series were Fundulus parvipinnis. The thirteen fishes mentioned above as having been used in the first of the long-time experiments (series 2) had been used in previous experiments and had been in the respiratory chamber seven days previously for a period of ten hours (series 1). Figure 1, a and b, contains the data for series 1 and 2. In 1a the data from the two series are plotted on the same time scale, in 1b the data from series 2 are plotted on a time scale one-fourth that of 1a. Groups 3, 4 and 5, the data for which are contained

![Graph](image-url)
in the chamber is completed.

The apparatus used will be described in detail in a subsequent paper. Briefly, it provides a continuous flow, constant temperature system, in which the rate of flow can be maintained at any desired value, and the temperature can be controlled to within 0.1°C. After the fishes are placed in the chamber they are in no way disturbed until the series of determinations is completed.

The oxygen was determined by the well-known Winkler method. The rate of flow was so adjusted that the amount of oxygen used by the fishes was never more than a third of that available. Preliminary experiments have shown that if no more than a third of the oxygen is used the pH of the water is barely affected.

Discussion of the Results.—The first group of thirteen fishes, run August 10, and again on August 17, 1931, shows that after six hours in the respiratory chamber the oxygen metabolism in each experiment had reached approximately the same level, and the general trend of the two curves is nearly the same for the first nine hours, at which time the first series was discontinued. Figure 1 shows the successive values of the oxygen consumed. The ordinates represent the oxygen consumed per gram of fish per hour, and the abscissas represent the number of hours from the time of transfer of the fish to the respiratory chamber. Although the values for these two series are approximately the same, it will be noted that on the second day of the second series (Fig. 1b) the values had dropped considerably lower and maintained this lower level each successive day until the experiment was terminated. There is no indication of an increase or decrease in the metabolic rate. The temperature for these two series was constant at 13°C., but in the case of the first series the fishes had been kept at that temperature for three days before being transferred to the respiratory chamber. After removal from the chamber they were placed in running sea water in the laboratory, which at that time was about 23°C. In the second experiment with these same fishes, however, they were taken directly from water at a temperature of 23°C., transferred
to the respiratory chamber and the temperature immediately lowered to 13°C. I shall return to this point later.

The curves 3, 4 and 5 in figure 2 represent the data obtained from the three weight-groups as stated above. Curve 3 is based upon 29 small fishes, curve 4 upon 22 medium-sized fishes and curve 5 upon 19 full-grown ones. The curve 3', figure 2, represents the results obtained from the 29 fishes of group 3 after an interval of 30 days. As the plotted data show, the respiratory metabolism of all four groups is considerably lower during the second twenty-four hours than during the first, and is likewise more constant. In three of the four cases the bi-hourly fluctuations which occurred during the first day were greatly reduced during the second twenty-four hours. This is most strikingly illustrated by the small fishes (curve 3, Fig. 2). The temperature in all four cases was 16°C. This temperature was chosen because it was that of the running sea water in the laboratory at the beginning of the last four series of determinations.

In the first long series (series 2, Fig. 1), done in August, 1931, I made determinations of the oxygen metabolism during the day only. At night the fishes were in total darkness. As a glance at the graph (Fig. 1b) will show, the final drop to the "normal" level occurred sometime during the first night. In the second of the long series (series 3, Fig. 2), there was a period from 8.00 P.M. until 10.00 A.M. in which no determinations were taken. It was also during the night in this case that the respiratory metabolism dropped to the level that I shall call "normal" metabolism.
In the three following series, however (4, 5, 3'), determinations were made at intervals of two hours throughout the duration of the experiment. In doing this it was necessary to expose the fishes to continuous light, whereas in series 2 and 3 they were undergoing the normal sequence of light and darkness. In these three last series the fishes did not reach a "normal" level until twenty-four hours or more had elapsed. In the first two, on the other hand, the normal level was attained sometime during the night. If, as I feel justified in assuming, the attainment of a "normal" metabolic rate at a given temperature depends on the time required for the fishes to become accustomed to their environment, then the more nearly normal the environment the less time will be required to attain it.

I have called attention to the fact that the fishes used in the first two series (Fig. 1) had been subjected to different temperatures before being transferred to the respiratory chamber. In the first series they had been kept at a temperature of 13°C. for a period of seventy-two hours previous to the time of transfer; in the second series the temperature was lowered from 23°C. to 13°C. immediately after they were transferred to the chamber. Their respiratory metabolism, however, followed the same trend in each case. It was such excellent duplication of results as the above, even when starting from different conditions, that led Keys (1930) to the assumption that after six hours the fishes had attained a normal rate of metabolism.

Although this first level, apparently representing a temporary equilibrium, is quite evident in most cases, it is not always manifest. In series 4 (Fig. 2) the values for the second six-hour period are of approximately the same degree of magnitude, while in curve 3 there is no indication of such a level. In the second six-hour period the fishes in groups 3' and 4 had approximately the same rate of metabolism, although those in group 3' were much smaller. If these values had been taken as representing "normal" metabolism it is quite obvious that they would have led to an absurd conclusion.

I have defined "normal" metabolism of fishes as that value of the respiratory metabolism obtained at any given constant temperature within their normal temperature range and which is maintained for a period of at least 12 hours at approximately the same level. This, of course, presupposes the following conditions: (1) That the fishes are normal and healthy, (2) that the values for the respiratory metabolism are taken at a certain definite time after the fishes have been fed in order to insure a standard nutritional state, and (3) that the species, the weight of the fishes and the temperature shall be stated. Furthermore, I have found that with Fundulus parvipinnis, any sudden disturbance will cause an immediate increase in the rate of metabolism, the effects of which may last for an hour or more. Other investigators (Keys, 1930; Adkins, 1931) have emphasized the advantage of using the continuous flow system.
ASTRONOMY: O. STRUVE

Although I feel justified in stating that fishes of this species do not reach a normal metabolic level until approximately twenty-four hours after they have been handled and transferred to a strange environment, I should not assume that this is true for other species of fishes. I should be doubtful, however, of the validity of data obtained on the respiratory metabolism of other species, unless the data covered a period of at least thirty-six hours, or unless the investigator had determined the time required for them to reach a "normal" level. For Fundulus parvipinnis, in view of the data for series 2, figure 1b, I feel confident that an average of values over a period of eight hours, after a lapse of twenty-four hours or more from the time of transfer to the respiratory chamber, represents "normal" metabolism. This is true at least for fishes weighing 6 grams, at a temperature of 13°C. Indeed, I should expect that with very active, "nervous" fishes several days would be required for them to reach a normal level of metabolism, while on the other hand, quiet, "sedentary" fishes may do so in a few hours.

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THERMAL DOPPLER EFFECT AND TURBULENCE IN STELLAR SPECTRA OF EARLY CLASS

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The broadening effect on spectral lines of the random motions of the atoms in an absorbing mass of gas has been thoroughly investigated theoretically, but has never been directly measured in stellar spectra. Following an important paper by W. Schütz,1 it was shown by M. Minnaert and G. F. W. Mulders2 that the integrated intensities of faint solar absorption lines fail to obey the classical expression of the absorption coefficient within the line, but that they are in harmony with Voigt's formula which takes account of radiation damping as well as of thermal Doppler effect. A similar use of the work of Schütz was made by A.