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OXYGEN CONSUMPTION IN AN ANTARCTIC HEMOGLOBIN-FREE FISH, *PAGETOPSIS MACROPTERUS*, AND IN THREE SPECIES OF *NOTOTHENIA*

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Abstract-1. The rate of oxygen consumption was determined in an Antarctic hemoglobin-free fish, *Pagetopsis macropterus,* and in three species of *Notothenia,* all of which have hemoglobin. In *P. macropterus,* the consumption at 0°C ranged from 0.012 to 0.022 ml O_2/g per hr, one-half to one-quarter of that in other fishes. In all cases, the rate was little affected by the oxygen tension in the water when it was lowered from approximately 160 to 20 mm Hg for *Notothenia,* or to 30 mm Hg for *P. macropterus.* In spite of the lack of hemoglobin, *P. macropterus* appears to have an efficient and well-regulated system for oxygen uptake.

INTRODUCTION AND METHODS

RUUD (1954, 1965) has pointed out that fishes of the family Chaenichthyidea, unlike other vertebrates, lack hemoglobin as well as erythrocytes. The oxygen capacity of their colorless blood equals that of normal plasma, e.g. only one-tenth that of blood in comparable hemoglobin-carrying fishes (Ruud, 1954; Scholander & Van Dam, 1957; Grigg, 1967). This raises some question as to whether the chaenichthyids are able to maintain a normal aerobic metabolism during activity. Since their sole habitat is the cold and oxygen-rich waters near Antarctica, it has been suspected that they depend on well-aerated water in addition to the benefit of a low metabolism resulting from the near-freezing temperatures.

During a stay at McMurdo Station (77°51'S, 160°40'E) in November 1966 we had a rare opportunity to work on a live specimen of these fishes; a *Pagetopsis macropterus* was caught unexpectedly in a fish trap at 75-m depth near the station. The fish was kept in an aquarium maintained at about -1°C for 2 weeks, during which time four experiments determining the oxygen consumption were made. The fish appeared to be in excellent condition throughout this period. The respirometer (2.881.) was kept in the dark, and the fish remained quiet while measurements were made. A control respirometer containing only water was run simultaneously. Oxygen determinations were made by a micro oxygen electrode calibrated with a tonometer and against a gasometric method (Scholander et al., 1955).

At Palmer Station (64°45'S, 65°05'W) in 1968, the same method was used to determine the oxygen consumption in some fishes which have hemoglobin, namely, *Notothenia nudifrons, N. gibberifrons* and *N. coriiceps,* caught in bottom traps in or near Arthur Harbor. The oxygen capacity of the blood was determined for all of these species. The blood was equilibrated with air at 0°C and analyzed by a micro gasometric method (Roughton & Scholander, 1943; Scholander & Van Dam, 1956).

RESULTS AND DISCUSSION

Examples of the basic data are shown in Fig. 1. In most of the runs, the rate of oxygen consumption decreases only slightly as the oxygen tension in the water decreases from about 160 to less than 20 mm Hg for the *Notothenia,* and to approximately 30 mm Hg for *P. macropterus*.

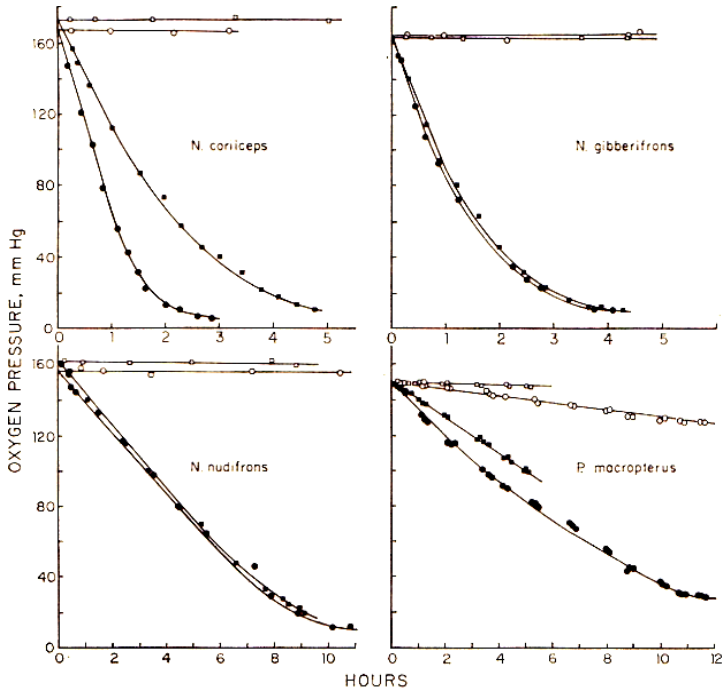

Fig. 1. Oxygen tension in the closed respirometer plotted against time. Each curve represents a different specimen, except those on P. macropterus, which are only duplicates. Open points are blanks, and closed points are fishes.

The oxygen consumption was calculated from the initial slope of the curves. The results are given in Table 1, which also includes other, shorter, runs. Whereas the oxygen consumption of the *Notothenia* falls within the normal range of other Arctic and Antarctic fishes (Scholander et al., *1953;* Wohlschlag, *1962),* the oxygen consumption of *P. macropterus* is considerably less. However, a zoarcid species, *Rhizophia dearborni,* from McMurdo Sound has a consumption of 0.01-0.02 ml O_2/g per hr (Wohlschlag, *1963)* which is very similar to that of *P. macropterus.* The difference in oxygen consumption among the three species of *Notothenia is* perhaps also reflected in the oxygen capacity of their blood (Table 2). Thus, *N. coriiceps* has the highest oxygen capacity, as well as the highest oxygen consumption, and it showed the most active behavior in captivity.

TABLE 1

OXYGEN CONSUMPTION IN *P. macropterus* AND THREE SPECIES OF *Notothenia*

	Oxygen consumption (ml O_2/g per hr)	Weight range
P. macropterus	0-017,0-022,0-016,0-012	76
N. nudifrons	0-022, 0-029, 0-035, 0-037,0-030	45-102
N. gibberifrons	0-044,0-049,0-042	103-282
N. coriiceps	0-061, 0-057, 0-066	145-283

The values represent different specimens, except for those of *P. macropterus,* which were obtained on a single specimen.

TABLE 2

OXYGEN CAPACITY OF BLOOD IN THREE SPECIES OF *Notothenia*

	Oxygen capacity (ml O_2/100 ml blood)
N. nudifrons	5.5,4.6
N. gibberifrons	5.7, 4.7, 4.5, 4.9
N. coriiceps	8.2, 8.8, 7.0, 8.2, 8.3, 8.0, 7.5

The values represent duplicate analyses on different specimens. Analytical uncertainty ±0.2 vol. per cent.

It appears from these data that the absence of hemoglobin in *P. macropterus* has not drastically reduced its metabolism. Perhaps a more striking finding is the fact that the oxygen consumption was so little affected by the oxygen tension in the water. Only when this dropped below 30 mm Hg was there a major change in the rate. With such an efficient mechanism for oxygen uptake at rest, one must assume that the fish can sustain an aerobic metabolic rate several times its resting value during activity in well-aerated water. It was noted that the ventilation rate remained essentially constant, 16-20 strokes/min, but that the ventilation volume, indicated by the amplitude of the gill covers, increased greatly as the oxygen content of the water decreased. A similar ventilation rate and increase in ventilation volume were observed in the *Notothenia* species. The dorsal fin of *P. macropterus* was raised and stretched whenever the oxygen content dropped markedly, suggesting that this may be an additional means for gas exchange in this animal. A substantial cutaneous respiration may take place, as other species of the family have well-vascularized skin and fins (Walvig, 1960). The gills, however, do not seem to be particularly well developed for efficient gas exchange (Steen & Berg, 1966). Therefore, the lack of hemoglobin may be compensated for mainly by a high cardiac output, high blood flow through the gills, and well-capillarized tissues.

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Key Word Index-Oxygen consumption; hemoglobin absence; Antarctic fish; Pagetopsis macropterus; Notothenia; blood without hemoglobin in fish.