Blood Gases of some Skink Lizards

by

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ABSTRACT

(1) Po_2 and Pco_2 of arterial and venous blood are studied in three skink lizards: the bean skink, **Mabui quinquetaeniata,** inhabiting the cultivated areas, and the two burrowing desert lizards; the ocellated skink, **Chalcides ocellatus** and the sandfish, **Scincus officinalis.**

The highest Po_2 in the arterial blood was that of the bean skink, while the lowest value of arterial Po_2 was recognized in the sandfish. On the other hand, CO_2 content of the arterial and venous blood was much greater in the sandfish than in the ocellated skink or the bean skink. The highly significant differences between the arterial and venous blood gases (Po_2 and Pco_2), due to acclimatization to low or high temperatures, may reflect the adapatation of these lizards to their habitats.

(2) Construction of the O_2 dissociation curves showed that blood of the sandfish has the highest oxygen affinity, while that of the ocellated skink has the lowest oxygen affinity.

In all three lizards, as body weight increased, the half saturation of blood (P_{50}) was decreased and the constants of the equation relating P_{50} to body weight differed from those calculated by Bennett (1973).

(3) The O_2 dissociation curves of the three lizards shifted to the left by low temperature and to the right by high temperature. At low temperature, the rates of shifting ($\triangle P_{50}/\triangle °C$) were found to be nearly the same in the three lizards, while at high temperature, the shifting was much greater in the case of the bean skink.

Regarding the Bohr effect, the rate of shifting ($\triangle Log\ P_{50}/\triangle pH$) in the sandfish was the hishest at high pH value, while at low pH value, the rate of shifting of the O_2 dissociation curve of the ocellated skink was slightly lower than that of the bean skink and the sandfish.

Variations in the rate of shifting of O_2 dissociation curves, due to temperature or pH values, in these three skinks may reflect the adaptation of these lizards to their habitat, and habits.

Introduction

Among lizards, the variation in oxygen affinity of their blood was attributed to the body size, activity and adaptation of the animal (Pough, 1973).

Oxygen delivery is enhanced by the trend for decreasing oxygen affinity with decrease of body weight. Bennett (1973) calculated a least square regression between oxygen capacity and body weight of lizards as log P_{50} (mmHg) = 1.973 — 0.0936 log W (gm).

It has been suggested that the low oxygen affinity, oxygen capacity and high thermal preferenda of desert lizards might create difficulties in the oxygen transporting function of their blood (Dawson, 1967 and Prosser, 1973). The effect of temperature on the 0_2 dissociation curves of five lizards, **Dipsosaurus dorsalis, Uma Notata, U. scoparia, Scleoporus occidentalis** and **Gerrhontus multicarinatus** was studied by Pough (1969) and it was found that such species showed an intra-specific variation ranging between 3-7 mmHg difference in P_{50} at temperature range between 25-40°C. The same author also found that the five lizard species possessed different sensitivities to the increased temperature according to the degree of thermophily. Wood and Moberly (1970) constructed the dissociation curve of blood at different temperatures and pH values and found that displacement of the curve was due to the concert effect of the two factors. The dissociation curve studies by Bennett (1973), in case of **Varanus gouldii** and **Sauromalus hispidus,** showed that oxygen affinity of the blood of both lizards was affected in the same manner by temperature and pH. The 0_2 dissociation curves were shifted to right by increasing temperature. The same author also found that in several species of lizards, as body temperature rose, the percentage of saturation of arterial blood fell significantly only during resting condition. Howell and Rahn (1975) pointed out that, as temperature increased from 20 to 40°C, the P_{50} value of blood of iguana would be more than double. Dawson (1975) and Pough (1976) reported that the oxygen affinity of lizard's blood is related to the activity temperature of each species.

Of much greater interest and functional significance is the influence of Pco_2 and pH on the oxygen affinity of blood (Bohr effect). As poikilothermic vertebrates do not maintain a constant pH as their body temperature changes, each temperature would require different pH if a physiological dissociation curve is to be described.

In the present study, measurements are made of 0_2 and $C0_2$ tensions of arterial and venous blood, as well as the 0_2 dissociation curves under different conditions of temperature. Such measurements are carried out on three different skink lizards belonging to different habitats and with different burrowing activities. The aim is to elucidate the respiratory functions of blood of these skink lizards and the variation of blood gases according to the variation of the habitat and habits.

Materials and Methods

Three lizards of the family Scincidae are used in the present study :

The bean skink, **Mabuia quinquetaeniata,** inhabits cultivated areas, is non-burrowing and does not hibernate or aestivate. The ocelluted skink, **Chalcides ocellatus,** a desert lizard, burrows in the drifts of loose sand and does not hibernate or aestivate. The sand fish, **Scincus officinalis,** a desert lizard, seldom appears on the sand surface and hibernates during winter. Lizards collected from the field were kept in the laboratory at normal temperature (25 ± 3 °C) and day light. They were fed on insects, mainly beetles.

Sampling of blood

The lizards were starved for at least 5 days before the measurements of different blood gases. Lizards were anaesthetized by using ether and left for some time (10 min.) for renewal of normal lung ventilation. One lizard was then opened in order to expose different blood vessels.

From the three studied lizards, arterial and venous blood was taken from dorsal aorta and postcaval vein. Heparin was used as an anticoagulant (1.000 USP units per ml of blood). The needle was held in a horizontal position and inserted into the blood vessel, so that the blood flows into the syringe without coming into contact with the atmosphere. Small steel mixing flea was inserted into the syringe to permit the stirring of the sample by using a magnetic collar and the following determinations were carried out :

a) Blood gases :

For blood gas analysis, the Corning 166 pH blood gas analyzer was used to measure pH, Po_2 and Pco_2.

b) Oxygen capacity :

The oxygen capacity was measured by fully oxygenating the sample with air at 25°C for 30 minutes equilibrium period. This period was found to be enough to saturate the blood with oxygen when exposed to atmospheric air (Wood and Lenfant, 1975). The sample was then analyzed for 0_2 content as partial pressure (mmHg) of oxygen (Po_2). In eighteen out of twenty instances, 0_2 capacity changed less than 10 % during the course of the experiment.

Construction of 0_2 dissociation curve :

For determination of the oxygen dissociation curve, samples of pooling blood from at least 5 lizards of each species were drawn from the postcaval vein into a heparinized syringe and one drop of 1 % sodium fluoride was added for every 3 ml of blood, to reduce the rate of glycolysis and to stabilize the pH. The blood was then kept on ice, 2 ml of the agitated blood were drawn into a 30 ml syringe, followed by successive amounts of nitrogen, oxygen and carbon dioxide, appropriate to the required partial pressures.

The Pco_2 was always kept at 40 mmHg throughout the experiment. The syringe was closed with a short blined length of small-bore rubber tubing and the syringe was rotated for 15 minutes at 37°C in a water bath. Care was taken to ensure that the plunger of the syringe was free to slide inside the barrel, so that the gas remained at atmospheric pressure. After 15 minutes, the syringe was removed from the water bath and a fresh gas mixture of the same composition was introduced into the syringe and the blood re-equilibrated for 20 minutes. The pH of the blood was measured and enough N-NaOH was added to ensure that the pH would be 7.21 in subsequent equilibration.

For the study of the effect of different temperatures on the respiratory functions of the blood, lizards were kept for at least one week at the experimental temperatures. This was achieved by dividing the lizards into three batches, each of which was put in a plastic container, which was, in turn, put in a separate (Lotus) incubator. Each of the three incubrators was adjusted at one of the three chosen temperatures: 10°, 25° and 35°C. All the incubated animals were exposed to light for 14 hours a day the rest of which they spent in darkness, in this way imitating normal light conditions during summer days.

The mean ± standard deviation was computed for each parameter. Statistical analysis of the data, including F-ratio and least significant difference (L.S.D.), was carried out. A statistically significant difference was assumed when $P < 0.05$, and at $p < 0.01$ the difference was considered as highly significant.

Results and Discussion

Analysis of blood obtained from the dorsal aorta and postcaval vein (Table I) showed that among the three studied lizards the arterial blood of the bean skink possesses the highest amount of 0_2, while that of the burrowing desert sandfish shows the lowest amount of 0_2. Such differences may reflect the effect of the high activity of the bean skink as compared to that of the other two lizards. The high blood Pco_2 during activity stimulates ventilation, leading to high Po_2 due to the increase of breathing, and thus a rise in arterial blood Po_2. The same observation was also made by Frankel et al. (1969) in the case of the red card turtle.

The arterio-venous oxygen difference of the bean skink was found to be greater than that of the two burrowing desert lizards; the ocellated skink and sandfish, which may again be attributed to the greater activity of the bean skink. This reflects the view that most of the oxygen carried by the arterial blood is consumed during passage through tissues. Similar low arterio-venous oxygen difference was also observed by Dawson (1967) and Prosser (1973).

Effect of burrowing behaviour on blood gases :

It is very interesting to show that, in case of the borrowing lizards (the ocellated skink and sandfish), the low oxygen transported by the dorsal aorta and the high Pco_2 of the both arterial and venous blood (Table 1), may be associated with the burrowing behaviour of these two lizards which remain all the time either in their burrows or submerged in loose sand. As a result, they are exposed to oxygen depletion. The carbon dioxide accumulated around them inside their burrows will lead to the decrement of arterial blood Po_2 and increase in the Pco_2 of the whole blood. The blood sensitivity of the burrowing lizards to co_2 was also described by Pough (1969), who compared the burrowing lizards **Uma notata** and **U. scoparia,** with a non-burrowing lizard; **Sceloporus occidentalis,** and showed that the high oxygen affinity and low sensitivity to co_2 of the blood of the burrowing lizards, were attributed to the burrowing adaptation and the hiding in rodent burrows.

Effect of temperature on blood gases:

Acclimatization of the three studied lizards, the bean skink, the ocellated skink and the sandfish, to different temperatures (10°, 25° and 35°C) showed a highly significant difference between their arterial and venous blood gases (Tables I, II). At low temperature (10°C), the oxygen content of either arterial or venous blood of these three lizards was increased above that of normal lizards but the rate of increase varied from one lizard to another. In the case of the hibernating sandfish, the increase of oxygen content (41.7 %) with decrease of temperature (25-10°C) may support the conclusion that the hibernating sandfish is less adaptable to low temperature than the burrowing ocellated skink (19.44 %).

At high temperature (35°C) (Tables I, II), the 0_2 content of both arterial and venous blood of the three studied lizards, was decreased below that of normal lizards.

On the other hand, co_2 contents of the arterial and venous blood of the studied lizards were increased above those of normal lizards. The degree of saturation with co_2 at high temperature was found to be compatible with the results found in several species of lizards by Pough (1969) and Bennet (1973); these findings were attributed to the fact that increase in temperature reduces the percentage saturation at constant Po_2.

Table I Effect of temperature on arterial and venous blood gases in dorsal aorta and postcaval vein of the lizard; bean skink, **Mabuia quinquetaeniata** and the burrowing desert lizards; ocellated skink, **Chalcides ocellatus** and sandfish, **Scincus officinalis.**

Species	*Po_2 (mmHg) ± S.D.*						*Pco_2 (mmHg) ± S.D.*					
	Low temp. (10°C)		*Normal temp. (25°C)*		*High temp. (35°C)*		*Low temp. (10°C)*		*Normal temp. (25°C)*		*High temp. (35°C)*	
	Arterial blood	*Venous blood*	*Arterial blood*	*Venous blood*	*Arterial blood*	*Venous blood*	*Arterial blood*	*Venous blood*	*Arterial blood*	*Venous blood*	*Arterial blood*	*Venous blood*
Mabuia quinquetaeniata	92.7 ± 1.33	33.6 ± 1.4	72.0 ± 1.80	28.5 ± 2.7	62.3 ± 0.63	26.9 ± 0.73	31.0 ± 1.12	34.0 ± 2.45	34.0 ± 2.6	41.5 ± 3.43	34.6 ± 1.9	44.2 ± 2.51
Chalcides ocellatus	81.7 ± 4.1	41.8 ± 2.53	68.4 ± 0.48	33.0 ± 0.98	61.2 ± 1.79	36.1 ± 2.77	42.0 ± 1.43	48.9 ± 0.93	33.4 ± 1.01	40.5 ± 1.7	35.9 ± 1.79	42.1 ± 2.65
Scincus officinalis	78.1 ± 0.59	37.4 ± 2.71	55.1 ± 2.9	34.7 ± 5.84	35.0 ± 1.5	26.6 ± 0.8	45.8 ± 0.16	53.8 ± 3.43	38.4 ±1.6	47.6 ± 4.65	43.3 ± 2.54	50.4 ± 4.23
F-ratio	** 36.85	** 12.96	** 79.07	** 16.15	** 489.8	** 39.26	** 210.3	** 68.4	** 9.6	* 4.9	** 19.88	** 7.09
L. S. D. @ %5	3.86	3.52	3.02	2.46	2.15	2.64	1.23	3.85	2.72	5.36	3.24	4.98
L. S. D. @ %1	5.42	4.93	4.24	3.46	3.02	3.7	2.29	5.41	3.82	7.52	4.55	6.98

Values are means ± Standard deviation.
* Significant at $P<0.05$.
** Highly significant at $p<0.01$.
@ L.S.D. = Least significant difference at 95 & 99 % significant levels respectively.

Table II Analysis of variance of arterial and venous blood gases obtained from dorsal aorta and postcaval vein of the lizard; bean skink, **Mabuia quinquetaeniata** and the burrowing desert lizards; ocellated skink, **Chalcides ocellatus** and sandfish, **Scincus officinalis.**

Species	F-ratio of differences at different temperatures			
	Po_2 (mmHg)		Pco_2 (mmHg)	
	Arterial blood	Venous blood	Arterial blood	Venous blood
Mabuia quinquetaeniata	564.8**	15.43**	4.20*	13.8**
Chalcides ocellatus	64.6**	16.20**	36.56**	22.63**
Scincus officinalis	510.79**	51.00**	24.71**	2.27

* Significant at $P<0.05$.

** Highly significant at $P<0.01$.

The variation in 0_2 content of arterial blood of the studied lizards, in relation to temperature of acclimatization, may also be explained on the basis of shunting of blood inside their hearts. The relatively high saturation of arterial blood at low temperature may be due to intraventricular shunting of blood from left to right. Such phenomenon was previously described by Steggerda and Essex (1957) and Millen et al. (1964), regarding non-crocodilian reptiles.

On the other hand, the low oxygen saturation of arterial blood of the three studied lizards acclimatized to high temperature, may also be due to intraventricular right to left shunting. Similar observation, in the case of turtles, had previously been discussed by Gatten (1974), who stated that a rise in temperature or activity level results in a decrease, or even a reverse (as during diving), in this shunt (left to right), then saturation in lungs will be seriously curtailed or abolished.

The arterio-venous oxygen differences decreased as the temperature of acclimatization increased from 10-35°C. Similar results were recognized in turtles (**Pseudemys scripta** and **Terrapene ornata**) by Gatten (1974), who concluded that the great importance of the relatively small arterio-venous oxygen difference emerged from :

a) The increase in heart rate and stroke volume, necessary to meet the added needs for oxygen transport which is called for by a rise in temperature or during activity.

b) Glycolysis as an energy source in these turtles during excercise.

0_2 dissociation curve

0_2-dissociation curves of the three studied lizards (Fig. 1), showed that the curve of the sandfish is located to the left, while that of the ocellated skink is to the right and in the bean skink it is intermediate, i.e. the oxygen affinity of blood is higher in the case of the burrowing desert sandfish than that of the bean skink or ocellated skink.

Half saturation (P_{50}) of blood and body weight

Differences in the values of half saturation (P_{50}) of blood of the three studied lizards with oxygen, were found to be affected by their body weights (Fig. 2), i.e. as the body weight increased, the P_{50} decreased. Generaly, it was found that the measured P_{50} values of the three lizards were somewhat lower than those calculated

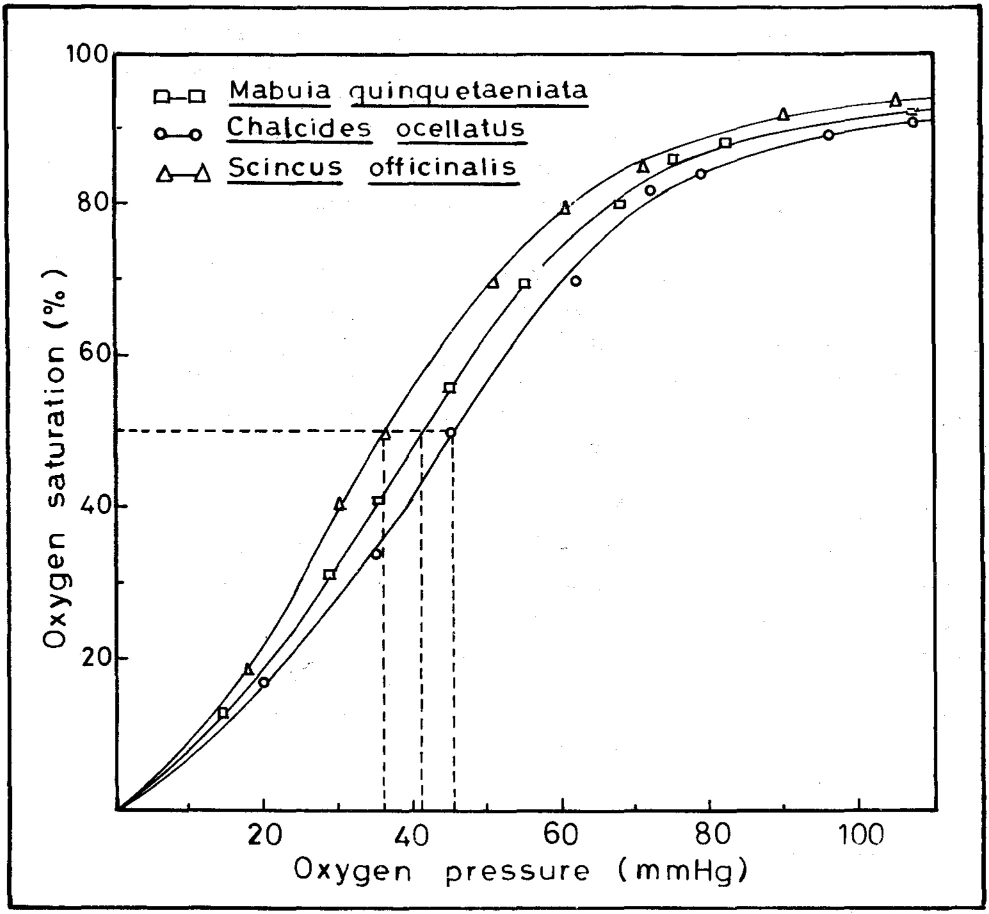

Fig. 1: Oxygen dissociation curve of the lizard, bean skink (**Mabuia quinquwtaeniata**) and the burrowing desert lizards, ocellated skink (**Chalcides ocellatus**) and sandfish (**Scincus officinalis**), at 25°C and pH = 7.21.

from the equation postulated by Bennett (1973), who related P_{50} with the body weight of the lizards :

$$\text{Log } P_{50} \text{ (mmHg)} = 1.973 - 0.0936 \text{ Log W (gm)}.$$

In the present study the constants of the equation calculated by Bennett (1973) have to be changed into :

Log P_{50} = 1.866 — 0.238 Log W for **Scincus officinals,**
Log P_{50} = 1.902 — 0.273 Log W for **Mabuia quinquetaeniata,** and
Log P_{50} = 1.688 — 0.223 Log W for **Chalcides ocellatus.**

Effect of temperature on O_2 dissociation curve

Determination of the dissociation curves of the three studied lizards acclimatized to different temperatures (10°, 25° and 35°C) shows that the three O_2 dissociation curves were shifted to the left by low temperature and to the right by high temperature (Figs 3, 4 and 5). Of the three studied lizards acclimatized to low temperature, the occellated skink was the one with the highest rate of shifting from the normal, ($\triangle P_{50}/\triangle °C = 0.86$) of the O_2 dissociation curve. In the case of those acclimatized to high temperature, the highest rate of shifting of the curve to the right was in the case of the bean skink ($\triangle P_{50}/\triangle °C = 0.75$) (Table III). This variation in the rate of shifting, due to acclimatization to low or high temperature, may reflect the adaptation of both burrowing lizards to their arid habitat, whereas the bean skink inhabits the cultivated areas and is not exposed to high temperatures or arid climates.

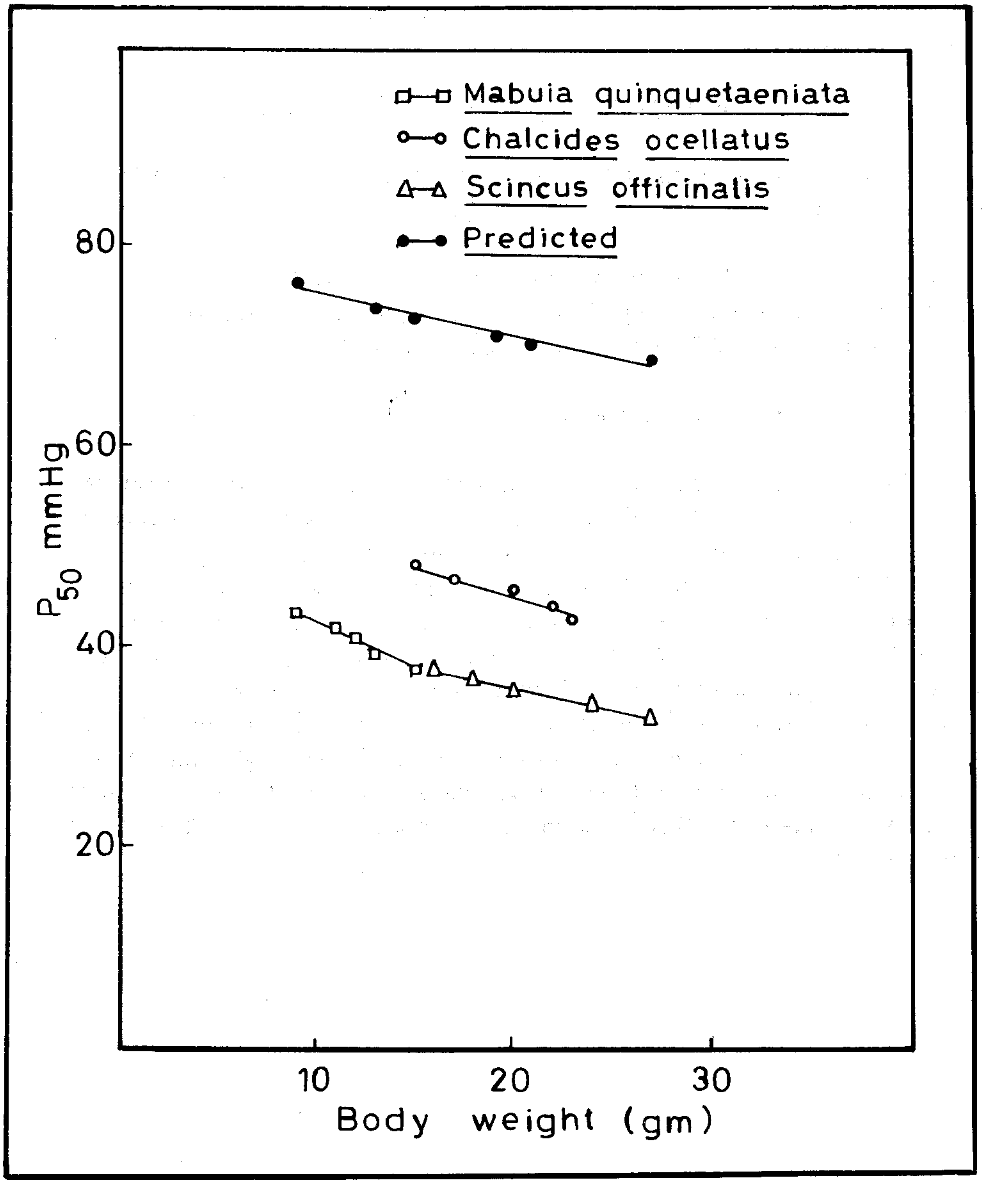

Fig. 2: The relationship between P_{50} and body weight of the lizard, bean skink **(Mabuia quinquetaeniata)** and the burrowing desert lizards, ocellated skink **(Chalcides ocellatus)** and sandfish **(Scincus officinalis)** at 25°C.

Table III Effect of temperature on half saturation (P_{50})of blood of the lizard; bean skink, **Mabuia quinquetaeniata** and the burrowing desert lizards; ocellated skink, **Chalcides ocellatus** and sandfish, **Scincus officinalis.**

Species	*P_{50} mmHg*			*$\Delta P_{50}/\Delta$ °C*	
	(10°C)	*(25°C)*	*(35°C)*	*Temp. = 10-25°C*	*Temp. = 25-35°C*
Mabuia quinquetaeniata	28.5	40.0	47.5	0.76	0.75
Chalcides ocellatus	32.5	45.5	51.0	0.86	0.55
Scincas officinalis	24.5	35.5	40.5	0.73	0.50

Table IV Effect of pH (Bohr effect) on the half saturation of blood of the lizard; bean skink, **Mabuia quinquetaeniata** and the burrowing desert lizards; ocellated skink, **Chalcides ocellatus** and sandfish, **Scincus officinalis.**

Species	*Log P_{50} (mmHg) at pH*			*△ Log P_{50}/ △ pH*	
at pH.,	*7.37*	*7.21*	*7.16*	*△ pH = 7.21 — 7.37*	*△ pH = 7.16 — 7.21*
Mabuia quinquetaeniata	1.455	1.602	1.676	—0.92	—1.48
Chalcides ocellatus	1.511	1.658	1.707	—0.92	—0.98
Scincus officinalis	1.389	1.550	1.607	—1.006	—1.14

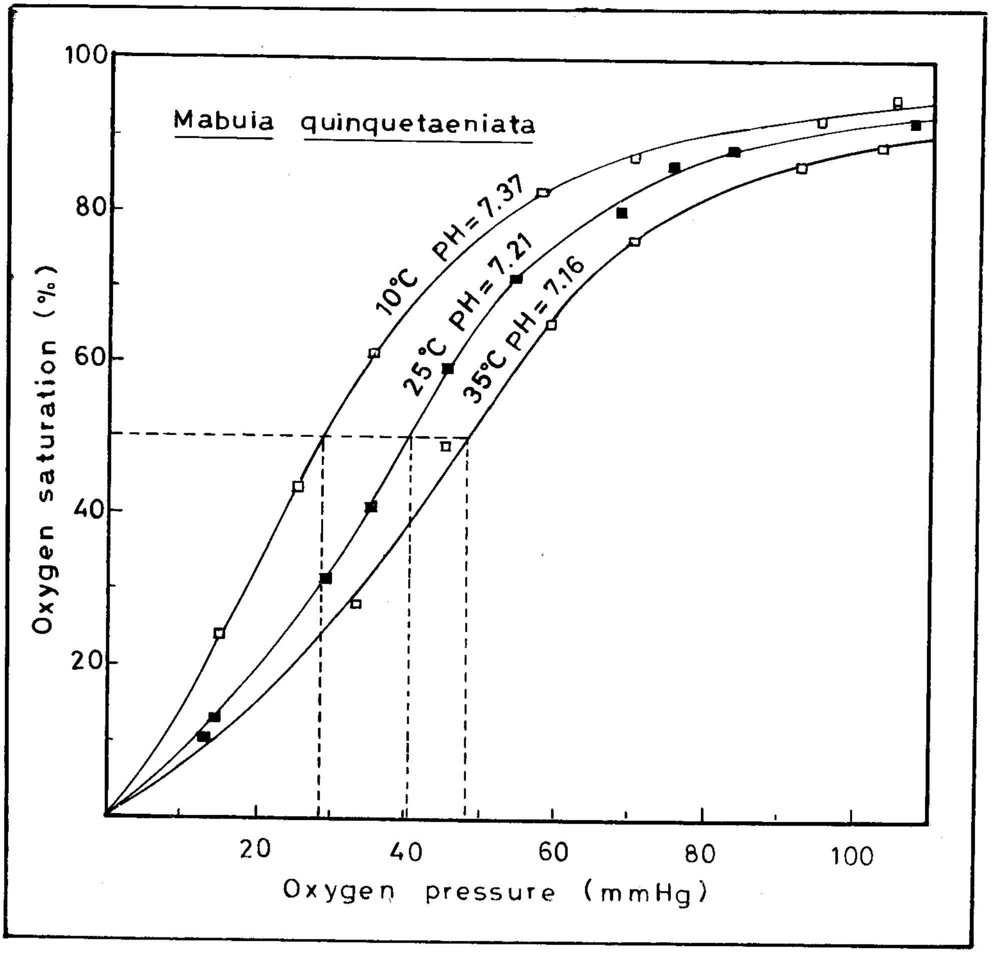

Fig. 3: Effect of different temperatures on the oxygen dissociation curve of the lizard, bean skink **(Mabuia quinquetaeniata).**

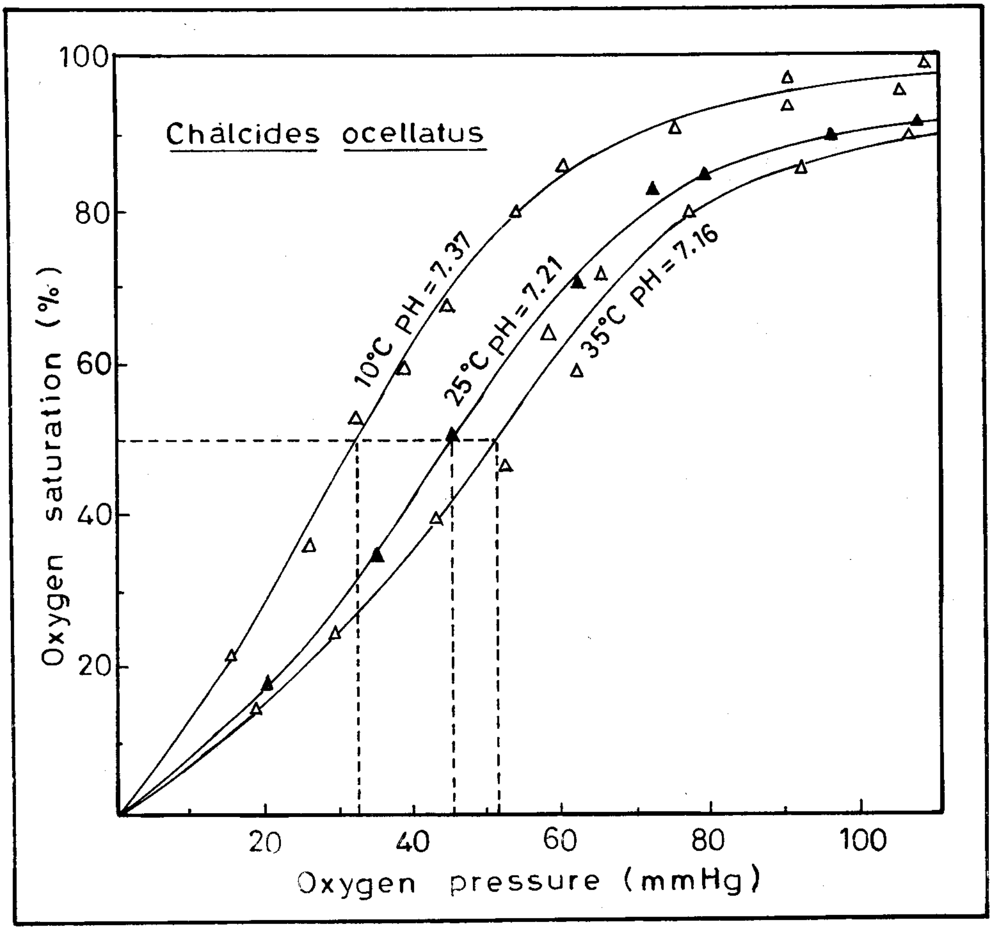

*Fig. 4:*Effect of different temperatures on the oxygen dissociation curve of the burrowing desert lizard, ocellatedd skink **(Chalcides ocellatus).**

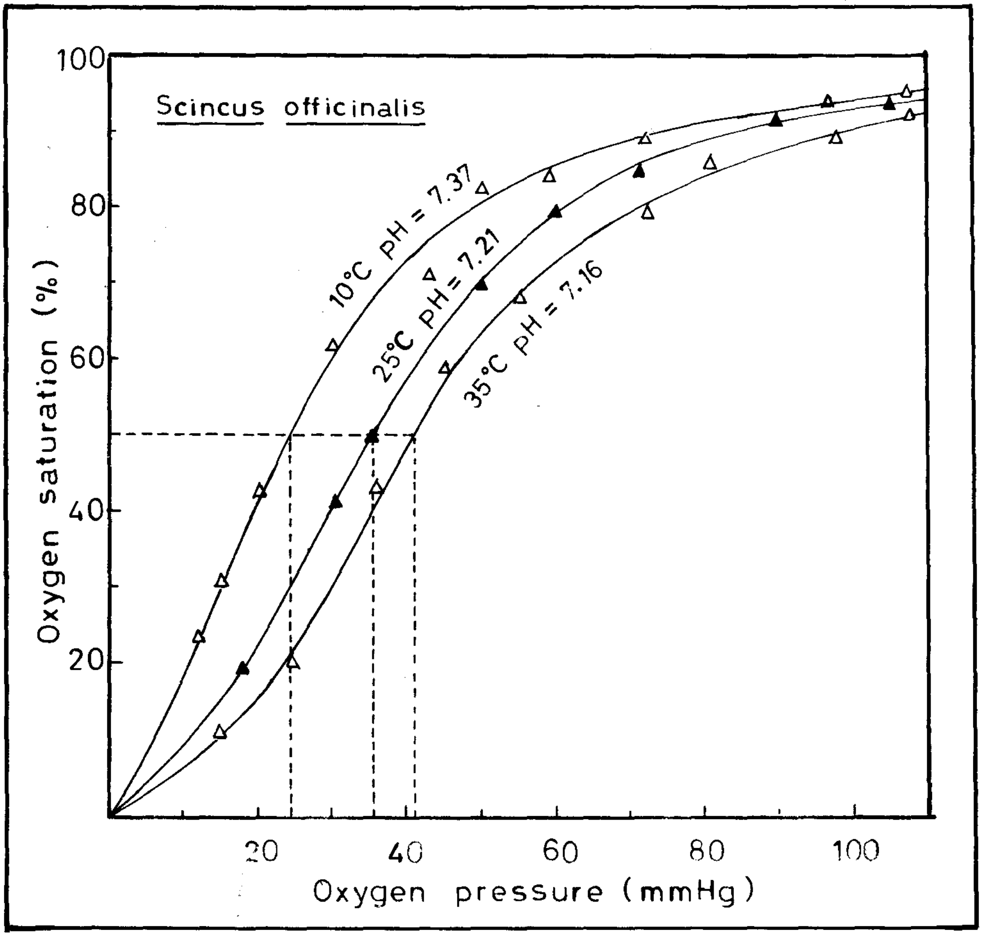

*Fig. 5:*Effect of different temperatures on the oxygen dissociation curve of the burroeing desert lizard, sandfish (**Scincus officinalis**).

These variations in the rate of shifting in the O_2 dissociation curves or P_{50} values, in relation to the adaptation of the animal, were previously discussed by Pough (1969), who found that the thermophilic lizard, **Dipsosaurus dorsalis,** had the greater O_2 affinity than **Gerrhonotus multicarinatus,** which was less thermophilic and had a low oxygen affinity. In 1970, the same author discussed the effect of temperature on the 0_2 dissociation curve of several lizards and found that P_{50} of iguanids was increased with temperature. However, he did not find any correlation between the P_{50} of anguid lizards and temperature. In this respect many attempts were also reviewed by Bennett (1973) for **Varanus gouldii** and **Sauromalus hispidus,** Gatten (1974) for **Pseudemys scripta** and **Terrapena ornata,** Howell and Rahn (1976) for reptiles in general and Pough (1977) for snakes.

Bohr effect

Studies of the O_2 dissociation curves of blood of the three lizards at different pH values, attained at different temperatures, showed a pronounced shift to the left at high pH values (attained at 10°C), i.e. increasing oxygen affinity, while the low pH values (attained at 35°C) shifted the curves to the right by decreasing oxygen affinity (Figs. 3, 4 and 5).

The rate of shifting of the O_2 dissociation curves is expressed as the change of Log P_{50} per unit change in pH ($\triangle$ Log P_{50}/ $\triangle$ pH) (Table IV). It appears that both Bohr effect and temperature act together to fix the position of the O_2 dissociation curves. Similar concert effect for Bohr effect and temperature on the O_2 dissociation curve was shown by Sullivan and Riggs (1967) in the case of turtles.

The rate of shifting of the curves differed among the three lizards at various pH values: In the bean skink and the ocellated skink, the rate of shifting at high pH (7.37) was slightly lower than that of the sandfish, and at low pH (7.17), the bean skink possessed the highest rate of shifting of the three studied lizards. This variation in the rate of shifting of the O_2 dissociation curves of the three lizards may reflect their adaptation to the cultivated or arid habitats. Pough (1969), during his study on iguanid and anguid lizards, found that the Bohr effect varied on systematic rather than ecological differences.

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غازات الدم لبعض سحالي عائلة سكنسيدي

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ملخـــــــــص

تمت دراسة الضغط الجزئي للاوكسيجن وثاني أوكسيد الكربون في الدم الشرياني والدم الوريدي لثلاث سحالى « تنتمي إلى عائلة سكنسيدي » وهي السحلية الخضاري وتقطن الاراضي الزراعية ، الدفان البري ودفان الرمال وتقطنان المناطق الصحراوية . وقد توصلت الدراسة إلى النتائج الآتية :

١ ـ يحتوي الدم الشرياني للسحلية الخضاري على كمية من الأوكسيجين أكبر من النوعين الآخرين ، وعلى العكس فان الدم الشرياني وأيضاً الوريدي لها يحتويان على كمية أقل من ثاني أوكسيد الكربون ، وهذا التغير يعود إلى اختلاف البيئة وأيضاً الي تكيف كل منهم لبيئته .

٢ ـ دراسة منحني التفكك الأوكسيجيني لدم الثلاث أنواع من السحالي أوضحت أن منحني دفان الرمال يقع في أقصى اليسار وهذا يدل على قابلية دم هذا الحيوان للاتحاد بالاوكسيجين أكثر من الأنواع الأخرى .

٣ ـ الضغط الجزئي للاوكسيجين اللازم لتشبع الدم بنسبه ٥٪ يتغير كلما زاد وزن الجسم وأن قيمة الثوابت التي تربط هذه النسبة من التشبع مع وزن جسم الحيوان تختلف عن القانون العام ويرجع ذلك الى تكيف هذه الحيوانات لبيئتها .

٤ ـ بدراسة تأثير درجات الحرارة المختلفة على منحني التفكك الأوكسيجيني وجد أنه ينحرف إلى جهه اليسار عند الدرجات المنخفضة ، وإلى اليمين عند الدرجات المرتفعه ، وهذا يعكس اختلاف قابلية الدم للاتحاد بالأوكسيجين مع درجات الحرارة . وقد وجد أيضاً أن معدل الانحراف يختلف في الأنواع المختلفة ، وهذا يعكس مدى تكيف الحيوان لبيئته .

٥ ـ بدراسة تأثير الوسط الحمضي والقاعدي والذي ينتج من تغير نشاط الحيوان وجد أن جميع المنحنيات تتأثر بهذا التغير ، وأن معدل انحرافها يعتمد على قدرة الحيوان للتكيف لبيئته .