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Oxygen consumption of the freshwater crab *Elamenopsis kempi* (Chopra and Das, 1930) from the Garmat-Ali river, Iraq*

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SUMMARY: The rate of oxygen consumption of the subtidal hymenosomatid crab *Elamenopsis kempi*, was studied from February 1988-December of the same year. The experiments were conducted by a Gilson respirometer over a wide temperature range (15-35°C), with the aim of estimating the individual oxygen consumption. Individual rate of oxygen consumption increased with increasing body mass at all temperatures for males, females and ovigerous females. The mean rate of oxygen consumption over the temperature range studied for the males varied from 1.20- 22.38 μl O_2 ind^{-1} h^{-1}, for the females from 2.05-20.73 and for the ovigerous females from 5.07-27.31 μl O_2 ind^{-1} h^{-1}. The metabolic rate of the males ranged from 0.130-0.63, of the females from 0.35-1.034 and of the ovigerous females from 0.309 -1.096 μ1 O_2 $mg^{-1}h^{-1}$ .The overall Q_{10} value was 1.92. The males were thermally sensitive at 15-25°C and compensate at 20-30°C, whereas the females, both non-ovigerous and ovigerous were compensating at all temperatures.

Key words: Oxygen consumption, Decapoda, Brachyura, Hymenosomatidae, *Elamenopsis kempi*, Garmat-Ali river, Iraq.

INTRODUCTION

The rate of respiration is a useful and sensitive measure of an organisms' daily expenditure of energy. The measurement of respiration can be so sensitive that it is modified by a great variety of factors, both internal and external, whose order of magnitude must be known before they can be ignored (Duncan and Klekowski, 1975). However, Duncan and Klekowski (1975) didn't mentioned the change in hydrostatic pressure as an external factor, which apparently has little effects on the rate of respiration in a migratory crustaceans *viz, Euphausia pacifica* Hansen, *Thysanoessa spinifera* Holmes and *Sergestes similis* Hansen (Pearcy and Small, 1968). Recently, Crisp (1984) and Lampert (1984) reviewed these factors. Davenport *et al*. (1980) investigated the effect of salinity on the oxygen consumption of *Pagurus bernhardus* L. and Venables (1981) studied the effect of size and temperature on the oxygen consumption of the amphipod *Talorchestia margaritae* Stephensen. Al-Dabbagh and Marina (1985, 1986) demonstrated the effects of starvation and temperature on the respiration rate of the terrestrial isopod *Porcelliodes* (=*Metoponorthus) pruinosus* (Brandt). More recently, Vaŕo *et al*. (1993) investigated the effects of temperature, salinity and oxygen tension on the rate of oxygen consumption of the nauplii of different strains of *Artemia*, and Rosas *et al*. (1995) analysed the effects of density and type of food on the rate of oxygen consumption of the larvae of the white shrimp *Penaeus setiferus* (L.).

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The hymenosomatid crab *Elamenopsis kempi* (Chopra and Das) is widely distributed in the lower Mesopotamia, Iraq. It is adapted to live among branches of the water plant *Ceratophyllum demersum*. The habitat is oligohaline brackish water with a salinity of 1.3-2.7‰ and a temperature range of 12-35°C attained in January and August. The area is well mixed and has a dissolved oxygen concentration of 5.8-10.9 mg 1^{-1} (Mohamad, 1989). *E. kempi* is one of the most important component of the invertebrate fauna of southern Iraq. It's population density has been recorded as 582 ind. m^{-2} (Ali, 1990), the mean annual production as 13.23 gDM m^{-2} yr^{-1} and the P/B ratio was ranged from 5.366-6.562 (Ali and Salman, 1998). It is obvious, therefore, that *E. kempi* must play an important role in the food web of this region. After establishing the population dynamics of the species (Ali *et al.,* 1995) and estimating its secondary production (Ali and Salman, 1998), the next step is to gather information on the oxygen consumption at the temperature range normally experianced by the species, so that the rate of metabolism of this crab can be calculated. The general objective of the present paper is to provide data on the oxygen consumption rate in terms of $\mu 1\ O_2$ ind.$^{-1}$ h^{-1} so as to estimate the population metabolism and construct an energy budget. In turn, this provides a measure of the role of the present species in the southern Iraq river system and finally facilitates further understanding of the predator-prey relationships in this region.

MATERIAL AND METHODS

The crabs (*Elamenopsis kempi*) used in the present study were collected from Garmat-Ali river at Basrah, and brought to the laboratory where they were placed in glass tank containing water from the same habitat of the crab, together with some branches of the water plant *Ceratophyllum demersum* and small pieces of the snail *Melanoides tuberculata*.

A Gilson differential respirometer was used for measuring the volume of oxygen consumed. Measurements were carried out within no more than two days from collection. Water temperature of the bath of the respirometer was fixed closer to that of the experimental temperature. The crabs were divided according to size, into males (mature and immature), non-ovigerous females (mature and immature) and ovigerous females (females carrying eggs in their body cavity). The non-ovigerous females are called females throughout this paper. Damaged specimens and newly moulted individuals were discraded. Usually a single crab was placed in each 7.5 ml respiration vessel, however in case of small crabs, two individuals were placed per vessel. The water was brought in from the same habitat of the crab. In order to avoid the effect of microorganisms, the water was filtered and warmed up to a degree close to the boiling point and then allowed to cool down to the laboratory temperature, where a gentle aeration was given. Three ml of this stock water were placed in each vessel. KOH solution (5%) was used as a CO_2 absorbance. Animals were equilibrated for one hour before the system was closed to the atmosphere and measurements of oxygen consumption commenced. At each run, six vessels out of 20 were used as controls. A reading was taken every 1/2 h. for 4 hrs. After calibrating the readings with those of the controls, the mean rate of oxygen consumption per animal per h ($\mu 1\ O_2$ ind.$^{-1}$ h^{-1}) was obtained. After the completion of each run, the animals were killed and dried for 24 hrs at 60°C, and the dry mass was measured.

Five test temperatures were used, these are 15, 20, 25, 30, 35°C. This temperature range is inclusive of that encountered by *E. kempi* in the field.

A regression equation of the oxygen consumption per individual and mass was calculated as follows:

$$R = a\ W^{b_1}$$

where R = rate of oxygen consumption ($\mu 1\ O_2$ ind^{-1} h^{-1}); W = dry mass (mg); a and b_1 constants.

Metabolic rate representing mass-specific respiration (R/W) was obtained from the following expression:

$$R/W = a\ W^{b_2};\quad R = (\mu 1\ O_2\ mg^{-1}\ DM\ h^{-1})$$

Separate relationships of the rate of oxygen consumption and metabolism were obtained for each sex at each of the 5 test temperatures. Ovigerous females were only tested at three temperatures (25, 30, 35°C) which represent the temperature range at which they were found in the field.

The homogeneity of the slopes of the different regressions were tested by the analysis of covariance. The significance of differences between the means at the various temperatures were tested by the Student Newman-Keuls multiple range test (Zar, 1974).

To demonstrate the effect of temperature on the size of the crab, the dry masses of the male crabs

(ranging from 5-35 mg) were divided into seven groups of 5 mg each, those of the females (ranging from 5-20 mg) were divided into 4 groups, and those of the ovigerous females (ranging from 5-25 mg) were divided into 5 groups. The rate of oxygen consumption was estimated for each mass group of every sex and for each temperature.

The temperature coefficient (Q_{10}) was estimated for each case as follows:

$$Q_{10} = (V_2/V_1)^{10/t_2 - t_1}$$

where V_1 and V_2 are the oxygen consumption at temperatures t_1 and t_2, respectively.

RESULTS

Oxygen consumption

The relationships of the rate of oxygen consumption (μl O_2 ind.$^{-1}$ h^{-1}) and the dry mass (mg) for males, females and ovigerous females of *E. kempi* held at 15, 20, 25, 30, and 35°C are given in Table 1. The slope (b), the correlation coefficient and the level of significance are also given in Table 1. It is apparent that the relationship in every case is linear and highly significant ($p < 0.001$). In the males, the slopes of the lines decreased with increasing temperature. No such trend was found in the females, as the highest value (0.939) was obtained at 25°C. The ovigerous females showed a highest value at 35°C. However, there was a general increase in the rate of oxygen consumption with increasing body mass of the crab at all temperatures for males, females and ovigerous ones.

TABLE 1. – Rate of oxygen consumption (μl O_2 ind^{-1} h^{-1}) as function of the dry mass (mg), for males, females and ovigerous females of *E. kempi* at temperatures 15-35°C. a = intercept; b = slope; n = number of observations. r = correlation coefficient.

Category	Temp. °C	a	b	n	R
females	15	0.5188	0.856	48	0.789**
males	15	0.5767	0.868	37	0.793**
females	20	0.8375	0.750	98	0.899**
male	20	0.8035	0.884	53	0.987**
ovigerous females	25	0.6683	0.759	36	0.676**
females	25	0.7227	0.939	30	0.894**
males	25	0.9332	0.821	45	0.983**
ovigerous females	30	1.5958	0.743	46	0.866**
females	30	0.9099	0.895	59	0.929**
males	30	1.0969	0.550	43	0.820**
ovigerous females	35	1.7258	0.858	40	0.848**
females	35	1.4028	0.890	44	0.873**
males	35	3.3880	0.531	45	0.786**

** $p < 0.001$

TABLE 2. – Summary of the test of covariance of the rate of oxygen consumption and the dry mass between males and females and females and ovigerous females of *E. kempi* at different temperatures. V_{R1}=test of homogeneity; V_{R2}=test of significance among different slopes (b); V_{R3}=test of significance of slopes (b) within each sex and between sexes, n = number of observations. m=males, f=females, o.f=ovigerous female.

Category	Temp. °C	n	V_{R1}	V_{R2}	V_{R3}
m x f	15	83	11.4465**	1.3980^{NS}	35.848**
m x f	20	80	2.8238^{NS}	3.0776^{NS}	2.450^{NS}
m x f	25	73	3.1600*	2.3470^{NS}	4.044*
f x o.f	25	64	6.7021**	1.0677^{NS}	12.273**
m x f	30	100	18.164**	17.372**	24.179**
f x o.f	30	103	10.4597**	2.0120^{NS}	18.722**
m x f	35	87	7.714**	13.4440**	1.650^{NS}
f x o.f	35	82	5.8630**	5.9035*	5.487*

NS = not significant; * = $p < 0.05$; ** = $p < 0.001$

Analysis of covariance of the specific oxygen consumption and temperature between males and females (Table 2) showd that the equations for each sex at each temperature were heterogeneous ($p < 0.05$ and $p < 0.001$) at all temperatures except 20°C. The results of the Student Newman-Keuls multiple range test indicated that the rate of oxygen consumption to body mass was not significantly different ($p > 0.05$) at 30-35°C (Table 3). In most cases the difference in the rate of oxygen consumption between the two sexes was significantly different.

Similarly a comparison of the regressions representing the rate of oxygen consumption between the females and the ovigerous females at temperatures 25°C, 30°C and 35°C showed that they were heterogeneous ($p < 0.001$) but their slopes were homogeneous at 25 and 30°C (Table 2). The rate of oxygen consumption of the two groups at each temperature was significantly different ($p < 0.05$ and $p < 0.001$). A comparison of the rate of oxygen consumption of males, females and ovigerous females, and of each group separately at the 5 different temperatures through the covariance tests are presented in Table 3. The results indicated that the relations were heterogeneous ($p < 0.001$). A comparison of the rate of oxygen consumption in the males, females and ovigerous females between different temperatures

TABLE 3. – Summary of the analysis of covariance of the rate of oxygen consumption and the dry mass of *E. kempi* at different temperatures. For further explanation see Table 2.

Category	n	V_{R1}	V_{R2}	V_{R3}
males	221	151.8506**	12.5772**	535.800**
females	208	25.8310**	0.9410^{NS}	150.000**
ovigerous females	120	11.9000**	0.2440^{NS}	9.922**

TABLE 4. – The regression coefficient (b), the correlation coefficient (r) and the level of significance of the specific metabolic rate versus dry mass for males, females and ovigerous females of *E. kempi* at each test temperature. Data expressed according to the formula: $R/W=aW^b$; R=μl O_2 mg^{-1} DM.h^{-1}; W = dry mass (mg).

Category	Temp. °C	a	b	n	r
Females	15	0.4742	-0.100	48	-0.162^{NS}
Males	15	0.4036	-0.319	37	-0.8162**
Females	20	0.7379	-0.176	29	-0.467*
Males	20	0.7906	-0.147	53	-0.725**
Ovigerous females	25	1.4893	-0.241	36	-0.379*
Females	25	0.7227	-0.060	30	-0.200^{NS}
Males	25	0.9172	-0.173	45	-0.734**
Ovigerous females	30	2.5118	-0.446	43	-0.375**
Females	30	0.8649	-0.092	59	-0.252*
Males	30	1.6368	-0.266	46	-0.513**
Ovigerous females	35	1.5523	-0.108	40	-0.190^{NS}
Females	35	1.3960	-0.100	44	-0.200**
Males	35	3.5809	-0.489	45	-0.773**

NS = not significant; * = $p < 0.05$; ** = $p < 0.001$

were significant ($p<0.05$)at most temperature ranges except 20-35°C in the males, 20-25°C in the females and 25-30°C and 30-35°C in the ovigerous females.

Mass-specific metabolic rate

The slope (b) for the relationships between mass -specific metabolic rate (μl O_2 mg^{-1} h^{-1}) and the dry mass of the crab are given in Table 4. In most cases the regression of log metabolic rate versus log body dry mass were linear and significant. Moreover, the decrease of specific metabolic rate with increase of mass was higher in the males than in the females at the 15, 25, 30 and 35°C .Whereas they were approaching each other at 20°C (Table 5). In the ovigerous females, however, it was higher than that of the non-ovigerous females.

The specific metabolic rate of the mass groups 5 and 35 mgDM at the temperature range studied (Table 5), for the males was ranging from 0.241-0.130 at 15°C and from 1.630-0.629 at 35°C, for the females was 0.404-0.351 at 15°C and 1.189-1.035 at 35°C and for the ovigerous females was 0.456-0.309 at 25°C and 1.305-1.097 μl O_2 mg^{-1} h^{-1} at 35°C. The average specific metabolic rate was 0.597 , 0.656 and 0.790 μl O_2 mg^{-1} h^{-1} for males, females and ovigerous females, respectively. However, the overall rate was 0.681 μl O_2 mg^{-1} h^{-1}.

Effect of size on oxygen consumption

The rate of individual oxygen consumption of the males and females at the 5 test temperatures and of the ovigerous females at 3 temperatures are presented (Table 6). The mean rate of the oxygen consumption of the males ranged from 1.2-22.3, for the females was 2.0-20.7 and for the ovigerous females was 5.0- 27.3 μl O_2 mg^{-1} h^{-1}. It is apparent that there was an increase in the oxygen consumption with the increase of fresh/dry mass and with increasing temperature. While no consistent differences in the rate of oxygen consumption were noticed between males and females, the ovigerous females showed noticeabely higher rate than the males (except in the mass group 8.89 mg FM/ 5 mg DM at 30 and 35°C), and the females at all temperatures inclusive. The high rate of oxygen consumption of the ovigerous females may be due to the respiration of the eggs which is added to that of the adults. Table 6, also includes the water contents of each mass group of *E. kempi*. It is clear that the water content increased with increasing body mass.

TABLE 5. – The specific metabolic rate (μl O_2 mg^{-1} h^{-1}) of each mass group (DM) of males (m), females (f) and ovigerous females (o.f) of *E. kempi* at each test temperature.

Temp. °C	category	Dry mass groups (mg) 5	10	15	20	25	30	35
15	m	0.241	0.193	0.169	0.155	0.144	0.136	0.130
15	f	0.404	0.377	0.362	0.351	—-	—-	—-
20	m	0.624	0.564	0.531	0.509	0.493	0.477	0.469
20	f	0.556	0.492	0.458	0.436	—-	—-	—-
25	m	0.694	0.616	0.574	0.546	0.526	0.509	0.496
25	f	0.656	0.629	0.614	0.604	—-	—-	—-
25	o.f	0.456	0.385	0.350	0.326	0.309	—-	—-
30	m	1.066	0.887	0.796	0.738	0.695	0.662	0.639
30	f	0.746	0.700	0.674	0.657	—-	—-	—-
30	o.f	1.225	0.899	0.751	0.660	0.598	—-	—-
35	m	1.630	1.161	0.953	0.828	0.742	0.679	0.629
35	f	1.189	1.109	1.065	1.035	—-	—-	—-
35	o.f	1.305	1.211	1.159	1.123	1.097	—-	—-

Average metabolic rate m = 0.597; f = 0.656; o.f = 0.790

TABLE 6. – Rate of oxygen consumption (μl O_2 ind^{-1} h^{-1}) of each mass group (fresh mass = FM; dry mass = DM) of males (m), females (f) and ovigerous females (o.f) of *E. kempi*. Figure inside parenthesis is the percentage of water in that group.

FM (mg)		8.89	19.88	32.33	46.04	58.90	63.10	76.24
DM (mg)		5	10	15	20	25	30	35
Temp.°C	category							
15	m	1.206	1.936	2.554	3.109	3.621	4.10	4.556
		(50)	(51)	(52)	(53)	(53)	(53)	(54)
15	f	2.057	3.724	5.269	6.740	—-	—-	—-
		(52)	(51)	(51)	(54)			
15	o.f	—-	—-	—-	—-	—-	—-	—-
20	m	3.126	5.610	7.600	10.07	12.158	14.18	16.151
		(50)	(51)	(52)	(53)	(53)	(53)	(54)
20	f	2.800	4.710	6.384	7.920	—-	—-	—-
		(52)	(51)	(51)	(54)			
20	o.f	—-	—-	—-	—-	—-	—-	—-
25	m	3.498	6.180	8.621	10.918	13.113	15.231	17.285
		(38)	(38)	(42)	(44)	(54)	(49)	(50)
20	f	3.276	6.281	9.191	12.041	—-	—-	—-
		(47)	(54)	(58)	(59)			
20	o.f	5.076	8.590	11.686	14.537	17.220	—-	—-
		(39)	(49)	(55)	(58)	(58)		
30	m	6.116	8.954	11.191	13.109	14.821	16.384	17.833
		(33)	(46)	(48)	(52)	(52)	(53)	(56)
30	f	3.842	7.145	10.271	13.287	—-	—-	—-
		(50)	(55)	(58)	(60)			
30	o.f	5.276	8.831	11.935	14.780	17.445	—-	—-
		(26)	(46)	(58)	(64)	(68)		
35	m	7.964	11.501	14.273	16.628	18.720	20.623	22.382
		(33)	(46)	(48)	(52)	(52)	(53)	(56)
35	f	5.962	11.117	16.007	20.731	—-	—-	—-
		(50)	(55)	(58)	(60)			
35	o.f	6.866	12.445	17.623	22.557	27.317	—-	—-
		(26)	(46)	(58)	(64)	(68)		

Temperature coefficient

The Q_{10} was calculated for each mass group of males and females, at 3 temperature ranges: 15-25, 20-30 and 25-35°C, and at temperature range of 25-35°C for the ovigerous females (Table 7). The Q_{10} values for the males ranged from 1.10-3.79. There was a noticeable increase in Q_{10} values with the increase of body mass at the temperature range of 15-25°C. But the situation was reversed at the other 2 temperature ranges. The Q_{10} values of the females ranged from 1.37-1.82. There was a general increase in the Q_{10} values with increasing body mass, except at the mass group 5mg at the temperature range 25-35°C. The Q_{10} values of the ovigerous females ranged from 1.35-1.58, and there was an increase of Q_{10} with increasing mass of the crab.

The overall mean Q_{10} for all groups, sexes and temperature ranges was 1.92, which means that there was a 2-fold increase in the rate of oxygen consumption with each increase of 10°C.

TABLE 7. – Temperature coefficient (Q_{10}) at three temperature ranges for each mass group of males, females and ovigerous females of *E. kempi*.

Mass group (mg)	category	Temperature range °C 15-25	20-30	25-35
5	male	2.90	1.95	2.27
5	female	1.59	1.37	1.82
5	ovi. female	—-	—-	1.353
10	male	3.19	1.59	1.86
10	female	1.68	1.51	1.77
10	ovi. female	—-	—-	1.44
15	male	3.37	1.41	1.65
15	female	1.74	1.60	1.74
15	ovi. female	—-	—-	1.508
20	male	3.51	1.30	1.52
20	female	1.78	1.68	1.72
20	ovi. female	—-	—-	1.55
25	male	3.62	1.21	1.42
25	female	—-	—-	—-
25	ovi. female	—-	—-	1.58
30	male	3.71	1.15	1.35
30	female	—-	—-	—-
30	ovi. female	—-	—-	—-
35	male	3.79	1.10	1.29
35	female	—-	—-	—-
35	ovi. female	—-	—-	—-

Mean: 1.92

DISCUSSION

The main features of the present results are, that there was an increase in the rate of oxygen consumption with increasing body mass of *E. kempi* and a decrease in the rate of metabolism with increasing mass at all temperatures. These results are in accor-

dance with the results obtained on other invertebrates (Brody, 1945; Kleiber, 1947; Zeuthen, 1947, 1953, 1970; Winberg, 1956; Hemmingsen, 1960; Marsden, 1979; Daoud, 1984; Al-Dabbagh and Marina, 1986). Also the increase in the rate of respiration and metabolism with increase of temperature in all groups of *E. kempi* were expected and are consistant with those obtained for other invertebrates (Kinne, 1970; Precht, *et al.,* 1973; Ivleva, 1980). The metabolic rate of *E. kempi* was 0.031 μmol O_2 mg^{-1} h^{-1}. This value is very close to those values given for an amphipod, mysidaceans, Plecoptera and some Diptera listed in Lampert (1984). This lower rate of metabolism of *E. kempi* is in accordance with its sluggish movement and perhaps to less energy expenditure in searching for food, as the crab is adapted to cling to the branches of the water plants where it gets food and shelter. The crab feeds on water plants and on invertebrates, mainly gastropods, common in this biotope. Moreover, the changes in response of *E. kempi* to different temperature ranges, due to changes in size and reproductive status are very well known in other invertebrates (see, Newell and Roy, 1973; Sastry and Vargo, 1977; Schatzlein and Costlow, 1978; Amsler and George, 1984; Jacobi and Anger, 1985; Al-Dabbagh and Marina, 1986).

The Q_{10} value is a very important indicator of the response of the animal to temperature (Sastry, 1979). Males *E. kempi,* at all sizes, are sensitive at the temperature range 15-25°C, compensate at 20-30°C and 25-35°C, except for a thermal sensitivity at the mass group 5 mg. The females and the ovigerous females were compensating at all temperature ranges.Thus the differences in response of the two sexes to constant conditions are possibly the result of different responses in a variable environment (Sastry and McCarthy, 1973). The compensatory responses of the female are very marked in *E. kempi*. Nevertheless, this is very much expected, as the experimental temperatures used here are 15-35°C, which are within the limit, the species is already adapted to in nature (12-35°C). However, this response is ensuring a normal activities under wide temperature fluctuations. This is another strategy undertaken by the species added to those reported earlier (Ali *et al*., 1995), which are: 1. reduced mortality of the broods, both at incubation (the eggs, unlike most crabs, are incubated inside an internal body cavity) and during the planktonic life, for the species is having an abbreviated larval development and without a megalopa stage 2. increasing the number of females in the population and increasing the number of broods produced by each female. In addition to a high rate of production *viz*. 13.23 gDM m^{-2} yr^{-1}.

The slopes of the regressions of the rate of oxygen consumption and dry body mass of *E. kempi,* ranged from 0.53-0.939. In most cases, these values were not significantly different from the general mean (0.81) for aquatic crustaceans (Winberg, 1950; 1956). However, Sushchenya (1970) gave a value of 0.75 for a number of crustaceans which again does note differ significantly from the previous value (Lampert, 1984). Moreover, several other authors gave values ranging from 0.5-1 (Klein-Breteler, 1975; Marsden, 1979). In fact, these variations are due to several factors (e.g. activity, nutritional status, gonad size, tidal rhythm and body size), which were either not considered or their effects were minimized to various degrees and are inevitable in the laboratory work. These are quite apparent through the scattering of the points of the respiratory relationships. Rao and Bullock (1954) emphasized that the precise estimate of the slope depends largely on minimizing of the scattering of these points to the nearest possible limits. In fact, this state, if achieved, would be of great value in the physiological studies in which the basal metabolism is preferably estimated, whereas the ecological studies rely more on the ordinary or routine metabolism, which reflects what actually occurs in the environment, more than the basal metabolism.

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