A C T A T H E R I O L O G I C A

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The Airing of Burrows of the Mole, *Talpa europaea* Linnaeus, 1758 *

[With 3 Tables & 12 Figs.]

The ventilation of burrows and nests of the mole, *T. europaea* was examined using the electric anemometer. The air flow in burrows is dependent mainly on the speed of wind over the ground. It was ascertained that air penetrates through fresh mole-hills into the tunnels. The intensity of air currents in burrows is rather much differentiated and depends on the configuration of tunnels, on their position in relation to the ground surface, and on the presence of mounds and openings. In all the nests examined air currents were recordable in the circular tunnels, whereas the chambers were quiet.

I. INTRODUCTION

Some aspects of the ecology of burrows, in particular their temperature and humidity, are relatively well known thanks to the papers of Strelnikov (1932, 1955), Rall (1939), Latyšev & Sidorkin (1947), Kalabukhov (1951), Novikov (1953), Kutscheruk (1960), Sokolov (1960), Sokolov & Varžnevskij (1962) and others.

The airing of burrows in mammals has not been examined as yet, despite the fact that people utilize it practically. For the use of any method of filling burrows of rodents with poisonous gases is based, among other things, on the phenomenon of air circulation in burrows.

The purpose of our investigations was to find correlations and regularities between the motion of air in the burrows and nests of moles and the scheme of these burrows and to examine these phenomena in various areas. An attempt was made to show the dependence of the ventilation of burrows and nests on the motion of air over the surface of the ground.

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II. METHODS

The electric anemometer produced by G. Lange K.G., Berlin (G.D.R.) with a range from 0 to 0.5 m/sec. and supplied with 6 V direct current was used to measure the circulation of air in burrows and nests of moles *Talpa europaea* Linnaeus, 1758. A detailed description of the methods of taking measurements was offered in the previous paper of these authors (Olszewski & Skoczeń, 1961). The apparatus turned out to be very much of assistance in this type of investigations.

The study area was for the most part the environs of Kraków. It included a pasture, 50 hectares in area, in places very densely inhabited by moles, where we took more than 600 measurements and another peaty pasture abounding in moles, with an area of 30 hectares, in which again about 600 measurements were taken. Some observations (248 measurements) were made in the Wolski Wood near Kraków.

III. RESULTS

The readings of measurements as well as the description of the localities of measurements and the order of operations are given below. The measurements of the ventilation of tunnels and those of the ventilation of nests are dealt with separately.

1. Ventilation of Tunnels

1.1. Sept. 19, 1961. Pasture with low, thick and matted sward. Compacted soil, tunnels with well-firmed walls. The feeler was introduced into a tunnel situated at a depth of 15 cm. On both sides of the feeler, at a distance of 1.5 m, there were molehills. The series included 107 measurements. The speed of wind 2 m above the ground was from 0 to 5 m/sec. Air pulsations in the burrow were synchronized with the blows of wind over the soil surface. The rate of the air flow in the burrows was reduced to 1—12 cm/sec. (Fig. 1). After the tunnel had been opened at a distance of 3 m from the feeler, the air pulsations in the burrow became more frequent and stronger and the draught became much stronger (Fig. 2). In this series 100 measurements were taken. The closing of the openings restores the original pattern of pulsations. A careful search of the adjacent portions of the tunnels revealed that there were no openings there. The air probably penetrated through the molehills.

1.2. On Sept. 21, 1961 the feeler was placed in a tunnel at a depth of 25 cm under the surface of the ground. The system of tunnels was furnished with a few entrances opening to the outside. A hundred and fourteen measurements were taken. The speed of wind over the surface of ground ranged from 0.5 to 6.0 m/sec. (Fig. 3), showing a close correlation with the air flow in the burrows (coefficient of correlation $r = 0.51$, Table 1).

1.3. Then a small plot, 2.5 m wide by 4.5 m long, with newly-formed molehills, was chosen, its burrows were cut off and the openings plugged with clay. Fig. 5 shows very great changes in the air circulation, after the burrows have been closed. The air pulsation has its minimum value, i.e., it lies within limits of 1—3 cm/sec. We then supposed that that amount of air penetrated through the molehills. After the hills had been made airtight with mud, the motion of air in the burrows was hardly perceivable and measurable.

1.4. The same experiment was repeated in a peaty pasture with light and loose soil. The results were identical. After closing the tunnels the air pulsations were almost completely subdued. The graph showed only the peaks corresponding to the strongest gusts of wind over the ground.

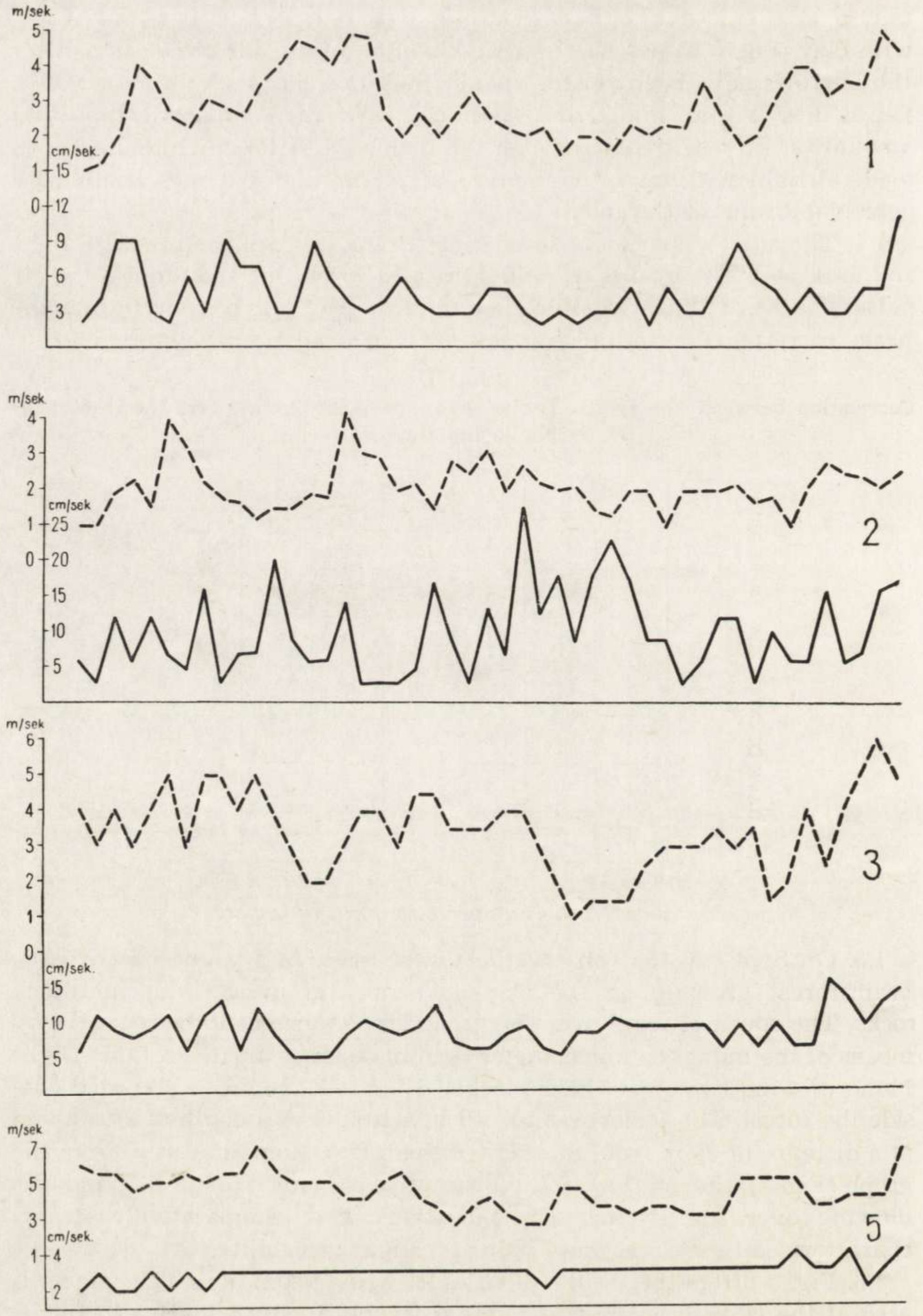
Table 1.

Correlation between the speed of wind 2 m. above the ground and the rate of air flow in the burrow.

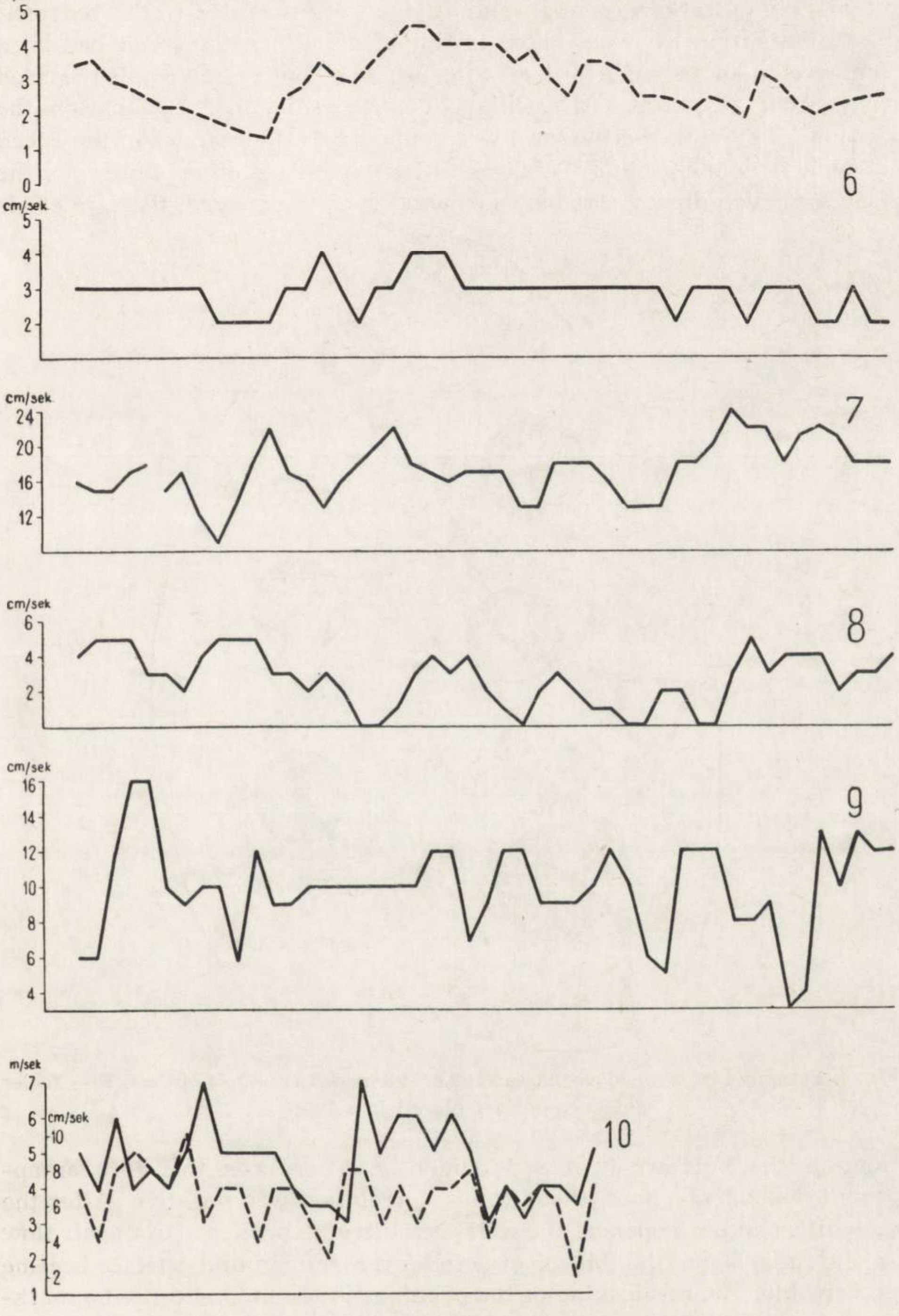
RATE OF AIR FLOW IN BURROW IN CM./SEC. \ RATE OF WIND 2 M. ABOVE GROUND IN M./SEC.	0.0–1.0	1.0–2.0	2.0–3.0	3.0–4.0	4.0–5.0	5.0–6.0
15–17						1
13–15			1		2	
11–13			4	8	7	3
9–11		1	1	2	3	
7–9	1	7	16	16	7	
5–7		1	8	12		
3–5	1	3	1			
1–3	1		7			

1.5. On Sept. 26, 1931 observations were made in a young beech-hornbeam forest growing on the clay-sand substratum overlying limestone rocks. The speed of wind over the ground was to small to be recorded by means of the induction anemometer used in our investigations. Only slight blows of wind, which at times reached 1.5 m/sec., could be recorded outside the forest. The feeler was placed in a tunnel at a depth of 20 cm and at a distance of 30 m from the edge of the forest. As will be seen from the graph (Fig. 7), the air flow in the burrows is obvious, though no wind was blowing over the ground. The pulsations were comparatively strong, characterized by a great amplitude and slight variability.

1.6. Fig. 8 offers the results of measurements taken in a clearing situated at the edge of a forest and rather steeply inclined toward it. In the clearing there were 29 molehills with an average diameter of 30 cm each. Rather rare and weak blows of wind came from the side of the elevation.



Figs. 1, 2, 3, 5. Explained in the text.
– – – – speed of wind 2 m above ground, in m/sec,
——— rate of air flow in burrows, in cm/sec.



Figs. 6—10. Explained in the text.

Strong air pulsations of small amplitudes were recorded in the burrows. Sixty measurements were taken in this place. When the feeler had been removed to another portion of tunnels, at a depth of 10 cm, it recorded very strong air pulsations, reaching 16 cm/sec. (Fig. 9). The changes in the rate of air flow in the burrows were opposed to the changes in the speed of wind over the ground. This was reflected, among other things, by the fact that even during soft blows of wind over the ground, the rate of air

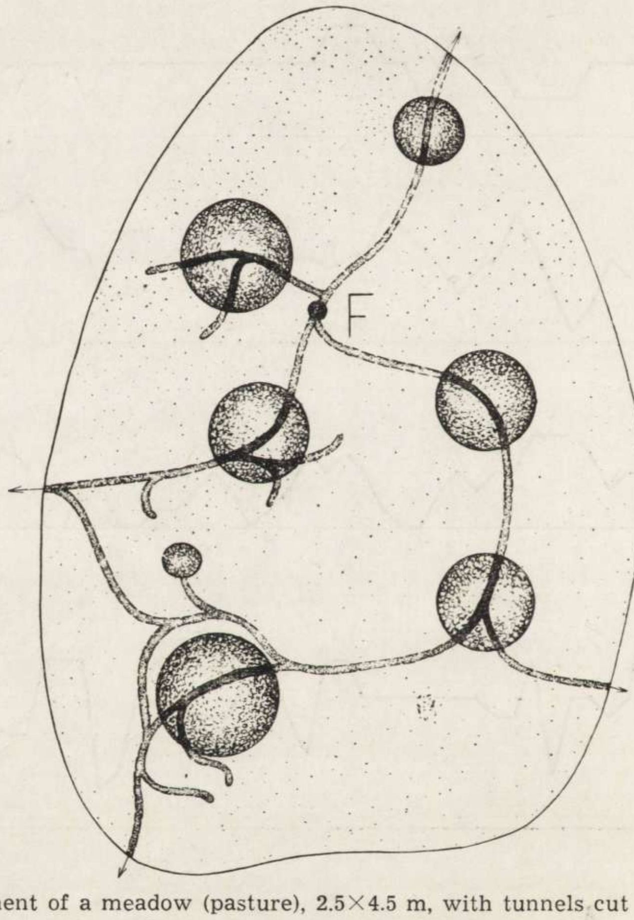


Fig. 4. Fragment of a meadow (pasture), 2.5×4.5 m, with tunnels cut off. F — feeler of anemometer placed in a tunnel.

flow in the burrows decreased evidently. There was, therefore, an apparent dependence here, though the correlation was negative. After the molehills had been opened, the well-seen direct dependence of the air flow in the tunnels on the blows of wind over the ground surface became perceivable. The re-blocking of the openings in the mound caused a marked drop in the rate of air flow so that at times it faded completely away.

2. Ventilation of Nests

2.1. On Oct. 4, 1962 a nest in a peat-bog was examined. The height of the molehill was 20 cm, its diameter 80 cm, and the dimensions of the chamber were 20 × 25 cm. The top of the nest chamber was at the level of the ground surface. Four entrances led to the chamber. The speed of wind 2 m above the ground surface was 1 m/sec. The feeler placed in the runway just near the chamber recorded a continuous though slight motion of air in the tunnel. When moved to the chamber, however, it did not show any traces of air flow.

2.2. Two nests were examined on the next day. The speed of wind over the ground was 0.8 m/sec. The characteristics of these nests were identical with those of the first one. A weak but steady air flow was recorded in the tunnels round the chamber, whereas the nest chambers (empty) were always quiet.

2.3. The measurements taken in another nest in the peat-bog on Dec. 20, 1961 were very interesting. The nest was situated by a lonely tree. The height of the mound was 40 cm, the diameter 110 cm. The chamber, 26 × 26 cm, had 4 entrances. Its floor was at a depth of 35 cm from the ground surface. The speed of wind over the ground reached 7 m/sec. The feeler placed in the circular tunnel recorded the air flow, which averaged 6.5 cm/sec. at times reaching 10 cm/sec. and it showed the great synchronism of the air flow with the blows of wind over the ground surface (Fig. 10). Placed in the chamber, the anemometer did not show any air currents. The chamber was entirely quiet, just as in the previous nests.

IV. DISCUSSION

Soil is an environment rich in CO_2. It is not difficult to calculate on the basis of the data presented by F r a n z (1950) that up to a depth of 45 cm the amount of CO_2 in pasture soil is 50—55 times as large as its amount contained in the atmospheric air (Table 2). Correspondingly, in cultivated soils this amount is 11—15 times, in soils of deciduous forests 11—12 times, and in arenaceous soils 8—10 times as large. In the light of these facts the physiological adaptations of the mole to this environment become clear. According to K o r ž u j e v & K o r e c k a j a (1962) the mole has the heaviest lungs (21.5% of body weight) of all small mammals, whereas in *Desmana moschata* (L i n n a e u s, 1758), which for the most part leads an aquatic existence, the lungs form 10.6% of body weight and in *Sorex araneus* L i n n a e u s, 1758, 9.5%. The clear-cut ecological correlations are also found in the mole blood, which forms 7.7% of its body weight, whereas in *Arvicola terrestris* (L i n n a e u s, 1758) and in *Micromys minutus* (P a l l a s, 1771) only 3.8 and 4.4% of body weight, respectively. In comparison with rodents the mole has also a larger amount of haemoglobin (12.1 g per 1 kg body weight against 7 g per 1 kg body weight in *A. terrestris)* (Koržujev & Koreckaja, 1962). The serological composition of the blood of the mole differs from that of the blood of other mammals, as well (Dąbrowski & Skoczeń, 1962).

Table 2.
The CO_2 content at various depths in various soils (after Franz, 1930, modified).

Type of soil	Up to a depth in cm.	Amount of CO_2 in %
Grassland	15 45	1.46 1.64
Cultivated soil	15 45	0.34 0.45
Deciduous forest soil	30 60	0.[illegible]3 0.39
Arenaceous soil	30 60	0.25 0.31

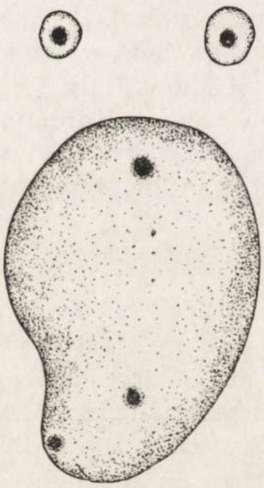


Fig. 11.

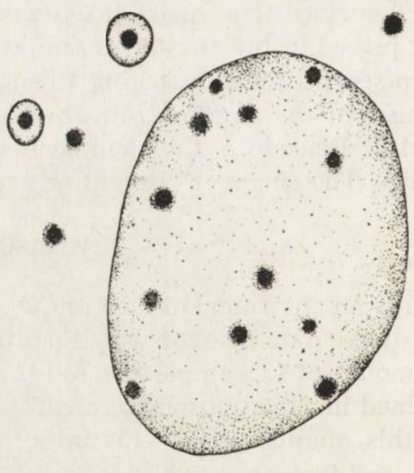


Fig. 12.

Fig. 11. Ventilating openings on the circumference and slopes of the mound (top view). Peaty meadow, Apr. 16, 1964.

Fig. 12. Another example of characteristic ventilating openings. Pasture, Apr. 16, 1964.

All the facts discussed above reflect clearly the environmental conditions of the mole and, at the same time, its adaptation to these conditions.

Characteristic ventilating openings in the maze of tunnels of the mole are observed, above all, in the vicinity of the nest and on the circumference of the nest mound or on its slopes (Figs. 11 and 12). They were also seen arranged along the tunnels after the first falls of sleet. And so, for example, on Dec. 8, 1961, when a sudden cooling followed the warm rain and a 30-centimeter layer of partially thawed snow was formed, numerous ventilating openings, mostly at intervals of 2—2.5 m, appeared in the tunnels of moles.

It has been supposed since long ago that the shape and structure of circular tunnels are connected with the ventilation of the nest (Rossinsky, 1900; Schaerffenberg, 1941; Baumann, 1949). Skoczeń (1958) dealt with the structure and characteristics of mole tunnels, introducing their division from the viewpoint of functionality. Our observations show that these complexes of underground burrows of the mole have also a definite system of ventilation. The air motion in the burrows is evidently dependent on the speed of the air motion over the ground. This fact is interesting because the speed of wind over the ground decreases with height, approximating to 0 just by the soil surface (Geiger, 1961). For example, the speed of air measured in the moor at a height of 2 cm on a windy day amounted to less than 1 cm/sec., at a height of 40 cm to 1.7 m/sec. and at a height of 180 cm it was 5.1 m/sec. (Alle et al., 1958).

In the case of an atmospheric calm the air flow is kept in the burrows probably on the principle of differences in air density, which result from differences in temperature.

Our observations indicate the fact that the ventilation of particular burrows is very much differentiated according to the differentiation of the tunnels, which divide into main ways with stronger air currents and side ways aired less intensely. Besides, the differences in the intensity of air currents in burrows are connected in all probability with other factors such as dead-end tunnels, the presence of an opening or a mound through which air penetrates at the end of a tunnel, the distance of the tunnel from the ground surface, and so on. These facts are undoubtedly of great importance to the mole in so far as its space orientation is concerned.

During our measurements, the air pulsation brought about by the steps of a man walking by in the proximity of the tunnel were clearly recorded by the anemometer. We suppose, by analogy, that a mole running in the tunnel may produce similar effects of compression, which probably become warning signals for other individuals present in the same tunnel.

When there is a layer of freshly-fallen, partially thawed snow or a thick layer of snow thawed on the surface, as well as after spring floods or heavy summer rainfalls, numerous ventilating openings turn up in the system of tunnels. Their aim is to intensify the air flow in the burrows and in spring, very likely, to warm them in as short a time as possible.

The concentration of CO_2 in the burrows inhabited collectively by mammals increases remarkably and then the ventilation of the burrows and the inflow of oxygen are indispensable. Kutscheruk (1960) writes that in the unusually complicated maze of tunnels of *Microtus brandti* (Radde, 1861) the number of new openings is larger in warm seasons than in winter. Also in this case the purpose, in addition to the thermoregulation in the burrows, is their proper ventilation.

The data concerning the ventilation of winter nests of moles are instructive. A complicated system of tunnels surrounding the nest chamber of the mole, in keeping with the early suppositions, is associated with the ventilation of the nest. During our measurements the feeler placed in the tunnels surrounding the nest chamber always recorded more or less strong air currents existing in them, whereas the nest chamber remained quiet in all these cases.

Burrows may also be important to human economy. In some regions they dry the soil, particularly so during dry seasons (Popova, 1962), whereas in watery regions burrows play the role of retention micro-reservoirs and they retain water. For this reason artificial tunnels made in cultivated ground by means of special mole drainers are sometimes applied for irrigation (Henderson et al., 1954). No doubt, this procedure is really of importance to human economy.

During our field observations in July of 1956, which, with its exceptionally low rainfalls (26.7 mm), was a dry month, mole tunnels running under the surface of a pasture were marked with tracks of dried-up grass. In April of 1958 on a farm near Kraków the tunnels of moles in a field freshly sown and harrowed brought about the formation of dry streaks on the soil surface.

The temperature of the surrounding soil has an undeniable and essential effect on the displacement of air in burrows. Soil, like water, is characterized by a great heat capacity: it warms and cools slowly and, in consequence, the fluctuations of the soil temperature are remarkably smaller than those of the atmosphere (Geiger, 1961). These facts are also reflected by the air temperature in burrows. In the summer, the deeper the position of a burrow, the lower its air temperature is, in the winter this relation is inverted. Table 2 presents single measurements of the air temperature in mole burrows situated at small depths. Abundant observational material on this subject is given by Kutscheruk (1960) and Sokolov (1960).

The temperature of winter nests of moles constitutes a particularly interesting problem. The position of the nest chamber depends on the specific ecological nature of the area. For example, in damp regions the nest chamber is sometimes situated so that its upper half is over the

Table 3.
Measurements of air temperature in burrows and nests of the mole (°C).

Peaty pasture, Dec. 8, 1962, 14h. Air temperature 2 m. above the ground, 1.3°		
Depth of burrows in cm.	Soil temp. in °C.	Air temp. in burrow in °C.
5	0.5	0.2
10	—	0.5
20	2.0	1.2
25	—	1.5
Dec. 10, 1962, 13h. Air temperature 2 m. above the ground, 3.5°		
5	— 0.6	— 0.2
10	0.6	0.7
20	1.0	1.5
30	1.8	—
Dec. 10, 1962, measurements of air temperature in nest chamber (outside nest)		
Hight and diameter of molehill in cm.	Distance of chamber from ground surface in cm.	Air temperature in chamber in °C.
25, 70	20	2.5
30, 100	30	3.0
30, 70	25	16.6 (inside of nest)

ground surface, and then it is, as a rule, covered with a big mound of loose earth charged with air. Single measurements of the temperature in the nest chambers and the temperature measurements taken inside the lair (Table 3) would indicate some great differences in the temperatures within the nest chamber itself. In the winter we found the walls of the chambers covered with hoarfrost in many cases, whereas the lair of the mole was dry and warm.

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PRZEWIETRZANIE NOR KRETA, *TALPA EUROPAEA* L I N N A E U S, 1758

Streszczenie

Przy zastosowaniu anemometru elektrycznego przebadano przewietrzanie nor i gniazd kreta (*Talpa europaea* L i n n a e u s, 1758). Przepływ powietrza w norach jest zależny głównie od szybkości wiatru nad powierzchnią gleby. Stwierdzono, że

powietrze przechodzi przez kopce świeżych kretówek do wnętrza chodników. Nasilenie prądów powietrza w norach jest dość zróżnicowane i uzależnione od konfiguracji chodników (główne trakty, odgałęzienia i tym podobne), od ich położenia w stosunku do powierzchni terenu, obecności kopców i otworów. Fakty powyższe mogą mieć także znaczenie przy orientacji przestrzennej kreta.

Zbadano również przewietrzanie zimowych gniazd kreta. Przypuszczenia o wentylacyjnej roli kanałów okazały się słuszne. We wszystkich badanych gniazdach dały się zarejestrować prądy powietrza w chodnikach okrężnych, podczas gdy komory pozostawały zaciszne.