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A REVIEW OF THE GENUS *ECHINOCOCCUS* RUDOLPHI, 1801

BY

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AND

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(Received for publication January 26th, 1963)

During a recent investigation in Kenya, *Echinococcus* adults were obtained from 25 domestic dogs (*Canis familiaris*), three hyaenas (*Crocuta crocuta*), three wild hunting dogs (*Lycaon pictus*), and a jackal (*Thos mesomelas*) (Nelson and Rausch, 1963). In view of the occurrence of several species of *Echinococcus* reported from South Africa by Cameron (1926) and by Ortlepp (1934, 1937), a detailed study was necessary before the specific status of the Kenya material could be determined. We were fortunate in having available reference material from various parts of the world.

As a result of this study it is concluded that only three of the 11 named species of *Echinococcus* can be distinguished by purely morphological criteria, six are regarded as synonyms of *E. granulosus* (Batsch, 1786), and the status of two is uncertain.

In a previous appraisal, Rausch (1953) recognized the following species as valid: *E. granulosus* (Batsch, 1786), *E. oligarthrus* (Diesing, 1863), *E. lycaontis* Ortlepp, 1934, and *E. felidis* Ortlepp, 1937; also, the species later described as *E. sibiricensis* Rausch and Schiller, 1954, and subsequently found to be conspecific with *E. multilocularis* Leuckart, 1863. *E. longimanubrius* Cameron, 1926, and *E. minimus* Cameron, 1926, were listed by Rausch (1953) as *species inquirendae*, probably identical with *E. granulosus*. *E. cameroni* Ortlepp, 1934, was listed as a synonym of *E. granulosus*. The status of *E. intermedius* López-Neyra and Soler, 1943, and *E. ortleppi* López-Neyra and Soler, 1943, was not discussed. More recent studies indicate that some of these earlier conclusions were erroneous.

Echinococcus granulosus (Batsch, 1786)

This species has become widely distributed as a result of the extensive movement of domesticated animals. It is indigenous at high latitudes on the North American and Eurasian continents, where the life-cycle involves the wolf (*Canis lupus*) and various species of deer. A variable anatomy has been observed in both adults and larvae. Some of the variations recorded in the strobilar stage may have resulted from different methods of collection and preservation, and those in the larval stage are partly due to the effect of different host species. Among the possibly existing biological strains of *E. granulosus* only now being investigated, one, *E. granulosus canadensis* Cameron, 1960, has been named on the basis of its peculiar host-parasite relationships and possible serological differences. Measurements and morphological data for *E. granulosus* are summarized in Table I. Further data are to be found in the comparative study of material from Kenya (Nelson and Rausch, 1963).

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Echinococcus multilocularis Leuckart, 1863

In the strobilar stage this species is distinguished by the number and distribution of the testes, by the position of the genital pore, and by the form of the gravid uterus (Rausch, 1953; Rausch and Schiller, 1954; Vogel, 1957; Petrov and Chertkova, 1959). The alveolar form of the larva is distinctive. Comparative measurements of adult specimens from Germany, Alaska and Siberia are shown in Table II.

TABLE
Summarizing some morphological characteristics

Species	Place of origin	Length of strobila	No. of segments	Location of genital pore
<i>E. granulosus</i>	Australia (domestic dog)	3.2 to 9.2	3	Near middle in mature segments; posterior to middle in gravid segments (Yamashita <i>et al.</i> , 1956; Plate I)
<i>E. granulosus</i>	England (domestic dog)	Up to 7.4	4 or 5	Posterior to middle of segments
<i>E. granulosus</i>	Alaska (domestic dog and <i>Canis lupus</i>)	*1.5 to 6	Usually 2; sometimes 3 or more	Near middle in mature segments; posterior to middle in gravid segments
<i>E. granulosus</i>	Siberia (domestic dog and <i>Canis lupus</i>)	2.7 to 5.4	3 to 4	In posterior half of segments
<i>E. granulosus</i>	Germany and Yugoslavia (domestic dog)	2.1 to 5 (av. 3.36)	3	Near middle in mature segments; posterior to middle in gravid segments
<i>E. granulosus</i>	Kenya (domestic dog)	2 to 3.5	3; sometimes 2 or 4	Near middle in mature segments; posterior to middle in gravid segments

* The validity of this figure is questionable; fully developed

E. multilocularis occurs at high latitudes in the northern hemisphere, from Canada and Alaska to Japan, Siberia and northern Europe. In nature, the adult cestodes are found in foxes (*Vulpes* and *Alopex*). The larvae develop in various species of microtine rodents.

Because of the unusual morphological and biological peculiarities of this cestode, a separate genus, *Alveococcus* Abuladze, 1959, has been proposed (Lukashenko and Zorikhina, 1961). While this proposal would seem to have at least as much merit as the establishment of separate genera for species of *Taenia sens. lat.*, it can be rejected on

similar grounds (Rausch, 1959). Morphological differences in the strobilar stage are not significant above the species level; the structure of the larva is distinctive, but, in view of the pleomorphism exhibited by the larval *E. granulosus* and of the inadequate knowledge of the larval stages of some other species of *Echinococcus*, it seems premature to erect a new genus on this basis. Host occurrence cannot be considered as a character of generic value.

I

of *E. granulosus* (all measurements in millimetres)

Testes		Size of cirrus sac	Hooks			Source of data
No.	Distribution		No.	Size		
				Large	Small	
45 to 65 (av. about 56)	From level of vitelline gland and ovary to near anterior margin of segment (Yamashita <i>et al.</i> , 1956; Plate I)	0.240 to 0.288 long	32 to 40; often 32	0.0369 to 0.0399	0.0257 to 0.0279	Yamashita <i>et al.</i> (1956)
48 to 64	Majority anterior to genital pore	—	30 to 36	0.028 to 0.035	0.023 to 0.025	Wright (1962)
45 to 65 (av. 56)	About equally distributed anterior and posterior to level of genital pore	Average 0.100 by 0.070	32 to 40	0.027 to 0.040	0.021 to 0.035	Rausch (1953, 1956)
32 to 40	—	0.225 to 0.266 long	36 to 40; often 36	0.032 to 0.043	0.020 to 0.036	Petrov and Chertkova (1959)
38 to 52 (av. 44)	About 2/3 of testes situated anterior to ovary	—	—	0.033 to 0.0398 (av. 0.0368)	0.022 to 0.034 (av. 0.0285)	Vogel (1957)
45 to 59 (av. 53)	Posterior margin to near anterior margin, confluent posterior to vitelline gland and ovary	Average 0.110 by 0.063	28 to 36	0.031 to 0.045 (av. 0.038)	0.019 to 0.039 (av. 0.0275)	Nelson and Rausch (1963)

strobilae of *E. granulosus* probably always exceed 2 mm. in length.

The differences in host-parasite relationships led Vogel (1957) to propose a sub-specific designation, *E. multilocularis sibiricensis* Rausch and Schiller, 1954, for *E. multilocularis* in North America. Recently Shul'ts (1961) (cited by Shul'ts, 1962) has proposed the name *Alveococcus* (= *Echinococcus*) *multilocularis kazakhensis* for a form of which the larva is reported to develop in sheep, but it is possible that this is a multicystic larva of *E. granulosus*. Further comparative experimental studies are required to determine reliable criteria for the recognition of distinct subspecies.

Echinococcus felidis (Ortlepp, 1937)

In the absence of knowledge of the larva, which was presumed to occur in wild ungulates, this species was distinguished primarily by the form of the rostellum hooks and by host occurrence (Ortlepp, 1937; Rausch, 1953) of the adult, which was known only from a lion (*Felis leo*) in South Africa. A critical appraisal of the limits of morphological variation in *E. granulosus* lessens the significance of the criteria used to separate *E. felidis*, including that of its occurrence in a member of the Felidae. In house cats, *E. granulosus* does not attain normal size or produce eggs (Lörincz, 1933; Drežančić and Wikerhauser, 1956). Although it has not been experimentally demonstrated that it will not do so in the

TABLE
Summarizing some morphological characteristics of four species
(all measurements)

Species	Place of origin	Length of strobila	No. of segments	Location of genital pore
<i>E. cameroni</i>	England (<i>Vulpes vulpes</i>)	5 to 7	4 or 5	Posterior to middle of segment in both mature and gravid segments*
<i>E. lycaontis</i>	Johannesburg Zool. Gardens (<i>Lycaon pictus</i>)	4 to 7 (av. 5)	Av. 5	Just posterior to middle of each segment
<i>E. lycaontis</i>	Johannesburg Zool. Gardens (<i>Lycaon pictus</i>)	4 to 6	Usually 5 ; sometimes more	—
<i>E. intermedius</i>	Almería, Spain (domestic dog)	3·3	4	Posterior to middle in mature and gravid segments (López-Neyra and Soler, 1943; fig. 3)
<i>E. ortleppi</i>	Vicinity of Pretoria, South Africa (domestic dog)	5 to 8·5	3	Middle in mature segments, posterior to middle in gravid segments

* Determined from examination

lion, Badinin (1947) (cited in Petrov and Lukashenko, 1962) identified cestodes from the intestine of a lion in the zoological garden of Samarkand as *E. granulosus*. *Echinococcus* adults were not found in four lions and 11 other wild felids in Kenya (Nelson and Rausch, 1963). The status of *E. felidis* remains uncertain.

Echinococcus cameroni Ortlepp, 1934

This species, which was found in the fox (*Vulpes vulpes*) in Great Britain, is based upon material previously identified as *E. granulosus* by Cameron (1926), from which it cannot be

distinguished on morphological grounds (Rausch, 1953) (Table III). The eggs in the terminal segment of some specimens indicated to Gemmell (1960) that *E. cameroni* might indeed be a valid species, since *E. granulosus* is not known to develop normally and to produce eggs in foxes (Matoff and Jantscheff, 1954; Gemmell, 1959). Sinclair (1956) found *Echinococcus* in six of 16 red foxes examined in Great Britain, mostly in Cardigan-shire; the maximum number of cestodes in a single animal was small (evidently 64), as seems typical of *E. granulosus* in foxes, but it was not stated whether eggs were present. Cestodes from dogs in England were studied by Wright (1962), who was unable to distinguish them from *E. granulosus* on morphological grounds. The situation in Great

III

of *Echinococcus* considered to be synonyms of *E. granulosus*
in millimetres)

Testes		Size of cirrus sac	Hooks			Source of data
No.	Distribution		No.	Size		
				Large	Small	
50 to 60	Extending well anterior to genital pore	—	28 to 32	0.035 to 0.038	0.030 to 0.033	Ortlepp (1934)
40 to 50	—	—	34 to 36	0.040 to 0.045	0.028 to 0.032	Ortlepp (1934)
About 40	Extending well anterior to genital pore	Av. 0.1 × 0.060	34 to 35	0.036 to 0.042	0.028 to 0.030	Rausch (1953)
52 to 60	Extending from posterior to ovary and vitelline gland into anterior portion of segment	0.080 to 0.100 × 0.038	38	0.035 to 0.038	0.024 to 0.030	López-Neyra and Soler (1943) ; López-Neyra (1947)
30 to 53	In middle portion of segment, leaving proximal and distal areas free	About 0.200 long	30 to 36	0.042 to 0.049	0.032 to 0.042	Ortlepp (1934)

of original material.

Britain is complicated by the apparent occurrence of *E. multilocularis*, a typical and fatal case of alveolar hydatid disease having been described by Walshe (1954) in a patient who had never been out of the country. The evidence for recognizing *E. cameroni* as a valid species is insufficient, and we consider it to be a synonym of *E. granulosus*.

Echinococcus patagonicus Szidat, 1960

This cestode was obtained from a fox (*Dusicyon c. culpaeus*) in the Argentine. Except for the rather few testes (Table II), it lacks distinctive morphological characteristics.

Szidat (1960) noted that the absence of eggs might indicate occurrence in an unnatural host. *E. patagonicus* is readily differentiated from the South American *E. oligarthrus* but rather closely resembles *E. granulosus*. Additional information is required to clarify the status of this cestode.

Species of Echinococcus Indistinguishable from E. granulosus

Five species, *E. intermedius*, *E. longimanubrius*, *E. lycaontis*, *E. minimus* and *E. ortleppi*, appear to be indistinguishable from *E. granulosus* and are considered synonyms.

Ortlepp (1934) originally differentiated *E. lycaontis*, from the hunting dog (*Lycaon pictus*), by the size and number of the rostellar hooks and by the number of segments, and on these grounds it was retained as a distinct species by Rausch (1953). Table III shows that the presumed differences fall within the limits of normal morphological variation for *E. granulosus*. The accessory hooks observed on the rostellum of this cestode probably represent an anomalous condition comparable to the situation observed by Vogel (1957) when similar hooks were found on specimens of *E. granulosus* from dogs in Europe. We have seen supernumerary hooks on *E. granulosus* from domestic dogs in Kenya. Extra rows of hooklets have also been reported on the scolices of *Echinococcus* larvae (Bolkhovitinov, 1957, 1959) (cited in Petrov and Lukashenko, 1962). Specimens obtained from three hunting dogs (*Lycaon pictus*) in Kenya were all identified as *E. granulosus* (Nelson and Rausch, 1963).

E. longimanubrius Cameron, 1926 (from *Lycaon pictus*), and *E. minimus* Cameron, 1926 (from *Canis lupus*), were separated from *E. granulosus* solely by characteristics of the rostellar hooks. *E. intermedius* López-Neyra and Soler, 1943, was described from two specimens from a dog in Spain. The described differences of all three species fall within the limits of observed variations of *E. granulosus* (Table III).

Cestodes from dogs in the vicinity of Pretoria were identified by Ortlepp (1934) as *E. granulosus*. After comparing Ortlepp's description with that by Leuckart, López-Neyra and Soler (1943) noted discrepancies which were considered to have specific value, and as a result they created a new species, *E. ortleppi*. Our data (Table III) do not substantiate this conclusion, and we accept Ortlepp's original determination.

SUMMARY

1. The genus *Echinococcus* Rudolphi, 1801, is reviewed. The recorded measurements of all species are shown in tables, and their taxonomic status is discussed.

2. Three species of *Echinococcus* can be distinguished by morphological criteria and are considered valid: *E. granulosus*, *E. multilocularis* and *E. oligarthrus*. The status of *E. felidis* and *E. patagonicus* is uncertain, but both may be conspecific with *E. granulosus*. Six species are considered synonyms of *E. granulosus*: *E. cameroni*, *E. intermedius*, *E. longimanubrius*, *E. lycaontis*, *E. minimus* and *E. ortleppi*.

ACKNOWLEDGEMENTS.—Comparative material used in this study was made available through the generous co-operation of Dr. T. W. M. Cameron, Institute of Parasitology, McGill University, Quebec; Dr. R. J. Ortlepp, Division of Veterinary Services, Department of Agriculture, Pretoria; Dr. Jean G. Baer, Institut de Zoologie, Université de Neuchâtel; Dr. Masashi Ohbayashi, Faculty of Veterinary Science, Hokkaido University,

Sapporo; and Dr. Benjamin D. Blood, Oficina Sanitaria Panamericana, Buenos Aires. The contribution of these persons is gratefully acknowledged.

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