

Table 1. YIELDS OF NEMATODE TRAPPING FUNGI ON THREE POLYSACCHARIDES AS A PERCENTAGE OF GROWTH ON THE EQUIVALENT WEIGHT OF GLUCOSE

	Dry weight (mg) per flask, glucose	Percentage of growth on		
		cellulose	starch	glucose glycogen
<i>A. oligospora</i>	88	66	134	90
<i>D. clavospora</i>	98	50	86	68
<i>D. thaumasia</i>	83	50	66	60
<i>A. anchonia</i>	68	10	32	32
<i>A. dactyloides</i>	75	100	50	10
<i>M. bembicoides</i>	82	0	0	12
<i>M. doedycoides</i>	80	134	68	80

liquid with four replicates in each treatment. Glucose in the basal medium could be replaced by that weight of carbohydrate containing the equivalent amount of carbon. Soluble carbohydrates were sterilized by filtration and added to sterile medium. Initial pH in all media was adjusted to 6.5 with 0.1 normal sodium hydroxide. Average dry weight yield per flask was measured on the previously determined day of maximum growth for each species. Shake culture was used only where insoluble carbohydrates were involved and growth on such carbon sources was rated by eye as a percentage of the growth produced in shaken culture on the equivalent amount of glucose.

For all fungi there were uniformly good yields on the hexoses and the pentose and for any species no significant differences were found between yields on these different carbon sources. Dry weight yields on glucose are given in Table 1. With the exception of *M. bembicoides* and *M. doedycoides*, yields on disaccharides were comparable with those on glucose. For these two species yields on maltose were 20 and 21 mg and on sucrose 6 and 15 mg, respectively, although both fungi grew well on cellobiose.

On polysaccharides all network forming species gave yields which were 50 per cent or more of those on glucose (Table 1). In contrast ring-formers showed a reduced ability to utilize these carbohydrates and yields were frequently below 50 per cent of those on glucose. Considering their ability to utilize disaccharides and polysaccharides, ring forming species clearly demonstrate a degree of loss in nutritional versatility. All species, except *M. doedycoides*, show reduced ability to utilize one or more of these carbohydrates. This is most pronounced in *M. bembicoides*, which cannot efficiently utilize maltose, sucrose, cellulose, starch or glycogen. This is correlated with its known low competitive saprophytic ability³. At the other extreme the ubiquitous network forming species *A. oligospora* has a high saprophytic ability³ and will efficiently utilize all the carbohydrates tested here.

It is almost certain that some nematode trapping fungi, particularly the network formers, exist as soil saprophytes, even if nematodes are available for capture, and can utilize relatively enduring substrates such as cellulose. Predaceous or saprophytic activity of at least some ring formers probably occurs only during a relatively short phase when ephemeral carbohydrate substrates such as hexoses are available as energy sources.

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¹ Cooke, R. C., *Ann. Appl. Biol.*, **50**, 507 (1962).

² Cooke, R. C., *Trans. Brit. Mycol. Soc.*, **45**, 314 (1962).

³ Cooke, R. C., *Ann. Appl. Biol.*, **52**, 431 (1963).

⁴ Cooke, R. C., *Ann. Appl. Biol.*, **54**, 375 (1964).

GENERAL

Structural Information and the Arrow of Time

I ACCEPT the criticism levelled by H. W. Woolhouse¹ against one of my examples². It was most misleading to suggest, as I did, that birds' eggs "feed" on the heat

supplied by (say) an incubator, for this heat does not flow into the eggs but merely reduces the rate of the flow of heat from them. Moreover, it is obvious that the developing embryo "feeds" on the yolk, and (like a heat engine) on the negentropy of the yolk.

It is, however, also of interest to stress that the total system, yolk plus embryo, vastly increases its structural differentiation during development. Admittedly, this system, like all heat engines, is a producer of entropy (which it has to get rid of: hence the flow of heat), so that its thermodynamic negentropy decreases. Nevertheless, this total system does not "feed" on (structural) negentropy: it does not suck "orderliness from its environment"³ but uses the genetic information contained in the zygote. While this information "increases" in the sense of being communicated to many new cells, it is used at the same time for controlling the development. This may make some of us hesitate to accept the well known claim that "the amount of information", like thermodynamic negentropy, can only decrease in being transmitted.

I am indebted to Woolhouse not only for his criticism but also for his defence against what he calls the "extravagant claims" of those who assert that "whenever structural negentropy is produced, the thermodynamic entropy must increase by the same amount", and I therefore hesitate to disagree with him even on one point; that is, on the crucial passage (pp. 70-75) in Schrödinger's beautiful and important book³. Yet in this passage Schrödinger was trying "to say something of organisms which distinguishes them from heat engines", to use Woolhouse's words. To show this, I have to quote a few passages from it³.

"What is the characteristic feature of life?" (p. 70). "It is by avoiding the rapid decay into the inert state of 'equilibrium', that an organism appears so enigmatic" (p. 71). "How would we express in terms of the statistical theory the marvellous faculty of a living organism, by which it delays the decay into thermodynamical equilibrium (death)? We said before: 'It feeds upon negative entropy', attracting, as it were, a stream of negative entropy upon itself . . ." (p. 74). "Thus the device by which an organism maintains itself stationary at a fairly high level of orderliness consists in continually sucking orderliness from its environment" (p. 75).

This last quotation, especially, contains a thesis which seems to me hard to reconcile with an increase of organization (of the total system of the egg) while it is not "sucking orderliness from its environment" (and perhaps even with the fact that an oil fired boiler is "continually sucking orderliness from its environment"). This I tried to convey in my admittedly misleading criticism².

My interest in this matter is not, however, any wish to criticize a great book, or a great man to whom I owe a personal debt for many exciting discussions. It is, rather, incidental to my criticism⁴ of the widespread view that the "arrow of time" (or time itself) is either an illusion or determined by entropy increase (or both). Like G. J. Whitrow I think that the view of those great physicists "who deny that time is 'real' or . . . seek to prove that it is a derivative concept of non-temporal origin"⁵ makes nonsense of most biological phenomena⁶, including the growth of scientific knowledge. This (we all hope irreversible) growth may well replace the time-reversible equations of particle mechanics by irreversible ones. There are many pointers in this direction.

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¹ Woolhouse, H. W., *Nature*, **213**, 952 (1967).

² Popper, K. R., *Nature*, **213**, 320 (1967); **207**, 233 (1965).

³ Schrödinger, E., *What is Life?* (Cambridge University Press, 1944).

⁴ Popper, K. R., *Nature*, **177**, 538 (1956); **178**, 382 (1956); **179**, 1297 (1957); **181**, 402 (1958).

⁵ Whitrow, G. J., *The Natural Philosophy of Time*, 311 (Thomas Nelson, 1961).

⁶ Whitrow, G. J., *The Natural Philosophy of Time*, 12 (Thomas Nelson, 1961).