Table 1. Systematic distribution of responses of bivalve hearts to acetycholine. Symbols: X, excitation; O, depression; OX, combination of excitation and depression; −X, excitation observed, but presence of depression not determined; numerical value, variable response, value of fraction is indicated as percentage of response.

Organism	Response
Subclass I—Protobranchiata	
NUCULANIDAE	
Yoldia thraciaeformis	−X
Subclass II—Pteriomorphia	
Order Taxodontida	
GLYCYMERIDAE	
Glycymeris subobsoleta	OX
Order Anisomyaria	
MYTILIDAE	
Mytilus californianus	X
M. edulis	OX/X, 63
Modiolus modiolus	OX/X, 86
PECTINIDAE	
Pecten caurinus	OX
Aequipecten irradiens	OX*
Chlamys hericius	OX
Hinnites giganteus	OX
ANOMIIDAE	
Pododesmus macroschisma	O
OSTREIDAE	
Crassostrea virginica	O
C. gigas	O
Subclass III—Lamellibranchia	
Order Heterodontida	
CARDITIDAE	
Cardita floridana	OX/O, 67
VENERIDAE	
Mercenaria mercenaria	O
Protothaca tenerrima	O
P. staminea	O
Tapes philippinarum	O
Compsomyax subdiaphana	O
Humilaria kennerleyi	OX/O, 80
Saxidomus giganteus	O
CARDIIDAE	
Clinocardium nuttallii	OX/O, 20*
Serripes groenlandicus	OX/O, 25
MACTRIDAE	
Schizothaerus nuttallii	OX
S. capax	OX
Spisula solidissima	OX
LUCINIDAE	
Phacoides annulata	OX
ASAPHIDAE	
Gari californicus	OX
SEMELIDAE	
Semele rubripicta	OX
TELLINIDAE	
Macoma secta	OX
Order Schizodontida	
UNIONIDAE	
Anodonta cataracta	OX/X, 28
A. grandis	OX/X, 78
Lampsilis siliquoidea	OX
Order Adepedonta	
SOLENIDAE	
Solen sicarius	OX
MYIDAE	
Mya arenaria	O
HIATELLIDAE	
Panomya ampla	OX
Panope generosa	OX
PHOLADIDAE	
Zirfaea pilsbryi	O
Barnea costata	OX*
Order Anomalodesmacea	
LYONSIIDAE	
Entodesma saxicola	O

* Excitation observed in the presence of benzoquinonium chloride (10^{-5} g/ml).

Pilgrim (*2*) observed diastolic arrest in *Mytilus canaliculus*, and we have observed it in *M. edulis*. Thus the hypothesis remains intact that acetylcholine is a transmitter substance of inhibitory cardiac nerves in bivalves. Second, excitation is also a nearly universal response. Excepting ostreids, every family from which more than one species has been tested includes at least one species which has provided some heart preparations which are excitable by high doses of acetylcholine (Table 1). This fact, and particularly such special cases as *Humilaria kennerleyi*, suggests that, when excitation cannot be demonstrated, the effect is masked in some way.

Benzoquinonium chloride (Mytolon) (10^{-5} g/ml) blocks both the depressor and excitor effects of acetylcholine. However, threshold and effectiveness of blockade are different for the two responses, and the relationship varies from species to species. For example, the depressor response of *Schizothaerus capax* heart is more effectively blocked than excitation. The opposite is true for the heart of another mactrid, *Spisula solidissima.*

The two effects of acetylcholine are clearly separable by their dissimilarity, by the lack of appearance of one or the other in some species (for example, *Saxidomus giganteus, Mytilus californianus*), and especially by the differential action of benzoquinonium chloride. A reasonable model of acetylcholine action on bivalve hearts should involve either two separate sites of action or two modes of attachment to the same site at high and low concentrations.

The general excitation of bivalve hearts by acetylcholine brings bivalve heart muscle pharmacologically into line with other well-known molluscan smooth muscle preparations such as the *Mytilus* anterior byssus retractor muscle (*11*) and the gastropod radula retractor (*12*). This is especially notable in quiescent heart preparations which in some cases are contracted by acetylcholine and in others are relaxed and induced to beat by 5-hydroxytryptamine. Furthermore, gastropod heart muscle has also been shown to be excitable by acetylcholine (*13*). Whether these excitatory effects are functionally homologous remains to be seen (*14*).

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References and Notes

1. A. Jullien and D. Vincent, *Compt. Rend.* **206,** 715 (1938); E. Florey and H. J. Marwin, *International Symposium on Nervous Inhibition,* E. Florey, Ed. (Pergamon, London, 1961), p. 136.
2. R. L. C. Pilgrim, *J. Physiol. London* **125,** 208 (1954).
3. J. H. Gaddum and M. K. Paasonen, *Brit. J. Pharmacol.* **10,** 474 (1955).
4. J. ten Cate and M. J. Reesinck, *Physiol. Comparata et Oecol.* **3,** 337 (1954).
5. J. H. Welsh and R. Taub, *Biol. Bull.* **95,** 346 (1948).
6. C. L. Prosser, *Comparative Animal Physiology* (Saunders, Philadelphia, ed. 1, 1950), p. 95.
7. R. L. Cox, *Proc. Malacol. Soc. London* **34,** 60 (1960).
8. C. M. Yonge, *Trans. Roy. Soc. Edinburgh* **62,** 443 (1953).
9. H. Irisawa, M. Kobayashi, T. Matsubayashi, *Japan. J. Physiol.* **11,** 162 (1961).
10. A. Jullien, *Compt. Rend. Soc. Biol. Paris* **119,** 603 (1935).
11. B. M. Twarog, *J. Physiol. London* **152,** 236 (1960).
12. R. B. Hill, *Biol. Bull.* **115,** 471 (1958); R. Fänge and A. Mattisson, *Acta Zool.* **39,** 53 (1958).
13. C. P. Jaeger, *Comp. Biochem. Physiol.* **4,** 30 (1961); J. Ripplinger, *Ann. Sci. Univ. Besançon.,* ser. 2, **8,** 3 (1957).
14. We thank the staffs of the marine laboratories at Alligator Harbor (Florida State Univ.) and Friday Harbor (Univ. of Washington) for their cooperation. We also acknowledge the technical assistance of T. Jegla and J. Scherer. The work was supported by grants from the University of Illinois Research Board and the National Institute of Health (grant H-6291).

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Effect of Rotation on Flowering Response of Xanthium pennsylvanicum

Abstract. The flowering response of *Xanthium pennsylvanicum* Wallr. is attenuated when the plant is rotated around a horizontal axis at the rate of 0.25 rev/min. Rotation prior to an inductive dark period has the strongest effect.

Xanthium pennsylvanicum is one of the most sensitive short-day plants. It can be maintained indefinitely in a vegetative state if grown under long-day conditions. However, it will initiate floral primordia if exposed to a single dark period in excess of 8.75 hours (*1*).

When young *Xanthium* plants are rotated around a horizontal axis, the leaves and the petioles of the rotated plants display strong epinastic responses within 24 hours, while stationary control plants show normal diurnal leaf movements (*2*).

The turntable of the plant rotator used for the experiment has a diameter of 4 feet. The turntable rotates in the same manner as a record player, but the rotating axis is horizontal rather than vertical. Plants were placed in holes on the turntable by hooks and rubber bands. The 24 holes were distributed evenly in a zone 10 to 20 inch-

Table 1. The effect of horizontal rotation at 0.25 rev/min and dark periods of different lengths on the flowering responses of *Xanthium pennsylvanicum*. All plants subjected to dark periods of 7.75, 8.25, or 8.75 hours were vegetative (stage 0) and are not shown.

Dark period (hr)	Flowering stage			
Rotated plants				
9.25	0	0	0	0
9.75	0	0	0	0
10.25	0	1	4	4
Stationary plants				
9.25	4	4	1	4
9.75	5	6	5	4
10.25	6	5	7	6

es from the rotating axis. The rotational velocity was 0.25 rev/min. The average light intensity at the plant surface was approximately 800 ft-ca, with a variation between 350 and 1000 ft-ca. The timing of the light-dark treatment was controlled by General Electric time clocks. The temperature of the experimental room was controlled by refrigeration. The air was circulated continuously by an electric fan. Temperature in the room ranged from 24° to 27°C during the experiments. The method reported by Lincoln *et al.* (*3*) was used to assess the flowering response.

Forty-eight plants, each having 6 to 8 mature leaves, were selected for uniformity from 200 plants. Each of the 12 treatments was repeated four times, for a total of 24 experimental plants and 24 controls. The control plants were placed on a bench near the rotator. At this time, the lights in the experimental room were on. The plants were subjected to treatment as follows: 2 long days and 3 days of variable light and dark followed by 1 long day. They were then taken to the long-day greenhouse and grown there until dissection.

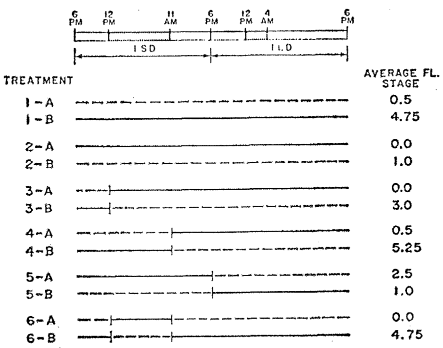

Fig. 1. Effect on the flowering response of *Xanthium pennsylvanicum* of rotation around a horizontal axis at 0.25 rev/min at different periods. Light treatment given during the rotation treatment is shown by open bar (light, 800 ft-ca) and cross-hatched bar (dark). The time is indicated above the bar. Light treatment of 3 long days given before the short-day (SD) treatment is not shown. All the plants were moved to the long-day (LD) greenhouse at the end of the rotation treatment. Dotted lines, plants being rotated; solid lines, stationary upright condition. Flowering response measurement is according to Lincoln *et al.* (*3*).

During the 3 days of variable light and dark there were six day-lengths: 7.75, 8.25, 8.75, 9.25, 9.75, and 10.25 hours of dark, respectively. All the dark treatments started at 2:00 A.M. The variable dark periods were provided by removing the plants in total darkness at appropriate times and transferring them to another room having the same temperature as the first. Both the rotated and the control plants were placed upright under lights in this second room. When the last treatment group (10.25 hours of dark) had been transferred to this room, all the plants were watered and then returned to their former positions, either on the rotator or on the bench in the experimental room.

Table 1 shows that flowering was suppressed in plants that were rotated. All plants subjected to a 9.75-hour dark period and rotated were vegetative, while the corresponding stationary controls had an average flowering stage of 5.0. Even with a 10.25-hour dark period, flowering of the rotated plants was much reduced.

To ascertain the effects of rotation before and rotation during the dark period, plants were removed from the rotator at various times during the treatment. At the same time, other plants were placed on the rotator in reciprocal treatments (see Fig. 1). The light treatment consisted of 3 long days, 1 short day, and 1 long day. The inductive period during the short-day treatment was 11 hours. The average flowering response of the stationary control plants was 4.75 (treatment 1-*B*), while that of plants rotated throughout the experimental period was 0.5 (treatment 1-*A*). The results of the various rotation treatments show that floral initiation appears to be most sensitive to rotation prior to the inductive dark period.

It is possible that there is a disturbance in the transport of metabolic products which affects the preinduction phase. The strong epinastic response of leaves seems to indicate a change in the auxin distribution pattern. Brain (*4*) has reported a marked change in the auxin diffusibility of rotated plants. The reduction in flowering by rotation may be due to disturbances of the polar transport, which may lead to an increase of auxin in the leaves. Thurlow (*5*) has shown that spraying indoleacetic acid on *Xanthium* inhibits flowering (*6*).

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References and Notes

1. K. C. Hamner and J. Bonner, *Botan. Gaz.* **100**, 388 (1938).
2. T. Hoshizaki and K. C. Hamner, *Plant Physiol.*, in press.
3. R. G. Lincoln, K. A. Raven, K. C. Hamner, *Botan. Gaz.* **117**, 193 (1956).
4. E. D. Brain, *New Phytologist* **41**, 81 (1942).
5. J. Thurlow and J. Bonner, *Am. J. Botany* **34**, 603 (1947).
6. Our investigation was supported in part by NSF grant No. 14380.

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Antigenic Structure of Plasmodium vinckei

Abstract. An erythrocyte-free preparation of the erythrocytic stages of *Plasmodium vinckei* was made from infected mouse blood and disintegrated in a Hughes press. Rabbit antisera yielded a series of precipitation arcs against plasmodial extract when examined by immunoelectrophoresis. No arcs developed when uninfected mouse erythrocytes or stromata were tested against the same antiserum.

In contrast to the antigenic analysis of bacteria, which has progressed rapidly both in breadth and in depth in recent years, analysis of protozoan cells is still in its infancy. Alone among the protozoa, the serotypes of *Paramecium* and *Tetrahymena* have been extensively investigated (*1*). Recent discussions of interspecies specificity deal chiefly with free-living and parasitic ciliates (*2*) and with parasitic flagellates (*3*). Among intracellular parasites the antigenic structure of *Eimeria stiedae* has been analyzed (*4*). To our knowledge, the separate antigenic components of intracellular stages of parasitic blood protozoa have not yet been demonstrated.

The present report records the antigenic fractionation of the erythrocytic forms of one of the rodent malarias, *Plasmodium vinckei*, with the aid of immunoelectrophoresis, according to techniques first described by Grabar and Williams (*5*).

We employed a strain of *P. vinckei* 100 percent fatal to white mice (*6*). In