active and is very productive. William Huckabee examined the relationship of cardiac output to the metabolic processes in the active muscles. He discussed the use of chemical substances, such as cyanide, arsenate, methylene blue, and dinitrophenol, to study the alterations in cardiac output that result from interference with normal metabolism.

In the cardiovascular field, the systems approach attempts to analyze in intact man or animals the sensing and resulting compensatory and control reactions which control blood flow at a level required to optimally meet bodily requirements. This approach, by its very nature, requires study of the man or animal involved in as untouched a state as possible. The multifaceted nature of the cardiovascular system requires recording of multiple variables in order that the investigator can get a picture of the state of the system as a whole. Such a knowledge of the practically or academically important facets of the system requires collection of much data. This can usually be accomplished without too much difficulty. However analysis of the moment-to-moment relationships of continuous recordings of many variables is a tremendous problem which, up to recent years, has usually bogged down such approaches.

The advent of electronic data processing, such as analog-to-digital and digital-to-analog conversion techniques, coupled with the use of analog and digital computers, will perhaps eliminate this stumbling block. Thus, the systems approach is becoming progressively more practical.

Most of the discussions at the symposium dealt with the systems approach. Homer Warner's presentation is an example of this approach in its more fullblown form. Warner mentioned that the rapid dilatation of the muscle vessels at the onset of exercise is accompanied by a transient decrease in arterial blood pressure. He demonstrated in dogs that this decrease activates the pressure receptors in the neck arteries; the receptors trigger cardiac acceleration and thereby facilitate the rapid increase in cardiac output. Using a computer to calculate beat-to-beat pressure flow ratios, he showed that when they were maintained constant by compression of the abdominal aorta during exercise, the exercise was no longer accompanied by an increased cardiac output.

Robert Marshall described the cardiac responses to exercise in normal man. In changing from the supine to the relaxed standing position there is an acceleration of the heart, a modest decrease in cardiac output, and, therefore, a considerable decrease in stroke volume. The mildest exercise in this position is sufficient to increase the stroke volume toward the values obtained when the subject is at rest and in the supine position. With increasingly severe exercise in the upright position, the heart rate continues to increase up to a maximum of about 180 beats per minute; the stroke volume only increases slightly. Athletes at rest and at equivalent grades of exercise have a slower rate and a greater stroke volume than nonathletes. However, the relative importance of changes in heart rate and stroke volume to the increased output is identical to that of sedentary subjects even at near maximal activity. During exercise there is no major shift of blood to the heart and lungs from the systemic circulation.

Eugene Braunwald showed that the cardiac activity is related to metabolic needs and that, under experimental conditions for a given work load, the same output can be achieved by various combinations of heart rate and stroke volume. He emphasized that some patients with heart disease may have normal hemodynamic values in the resting state and showed the advantages of exercise as a stressful stimulus to make manifest the disability. When there is damage to the muscle fibers of the left ventricle, the heart may pump out as much blood during mild exercise as it does in a normal person. Using markers attached to the wall of the left ventricle, he estimated the changes in the dimension of this chamber with each heart beat at rest and with exercise. Unlike healthy subjects, patients with myocardial damage achieve a greater force of cardiac contraction by increasing the filling pressure of the left ventricle, thereby causing a greater stretch of the muscle fibers before the onset of contraction.

With the onset of exercise, the vessels that control the flow to the muscles of the exercising limbs dilate almost instantaneously because of a local but unknown mechanism. In the nonexercising limbs, these vessels are reflexly constricted so that as the blood pressure rises with increasingly severe exercise, the flow through the nonexercising parts stays the same or decreases slightly. Thus, the increase in cardiac output with exercise is distributed to the active muscles.

John Shepherd also showed that exercise is accompanied by a reflex increase in tone of the capacitance venous system both in the exercising and nonexercising parts and that this increase is graded to the severity of the exercise. Since the greater part of the blood volume is contained in this system, its decreased compliance facilitates the return of blood to the heart during exercise.

Although the function of the heart is normally regulated by the autonomic nerves, it can function surprisingly well without them. David Donald reported that dogs exercising in the laboratory achieved the same cardiac output and oxygen consumption before and after cardiac denervation. In fact, the racing greyhound, after complete denervation, can, over the standard racing distance of ½ kilometer, achieve speeds 95 percent of those obtained prior to denervation. Since the increase in heart rate was limited, stroke volume caused a much greater increase in output in denerved dogs than in normal dogs.

EARL H. WOOD
Mayo Clinic, Rochester, Minnesota

Air Pollution

Health problems caused by air pollution were discussed at a symposium held during the American Medical Association's Congress on Environmental Health Problems, Chicago, Illinois, 1–2 May 1964.

Air pollution, according to Vernon G. MacKenzie (U.S. Public Health Service), is a variable dependent on climatic conditions, source and extent of pollutants, and the chemical nature and reactions of materials in the atmosphere. Of particular medical interest are the oxidants, sulfur dioxide and various oxides of nitrogen released from stacks, and benzo[α]pyrene and other hydrocarbons from incomplete combustion. William S. Spicer (University of Maryland) and Reginald H. Smart (Los Angeles) described the special situations involved in excess mortality at Donora, Pennsylvania, and London. Spicer discussed Tokyo-Yokohama asthma, which has been shown to occur in previous nonasthmatic persons who move into this area. They almost immediately begin to experience difficult breathing. The source of pollu-

tion is primarily industrial stacks. In London the principal contaminant appears to be the various components and derivatives from the combustion of coal, while in Los Angeles automobile emissions contribute the main atmospheric burden.

The ability of a community to control atmospheric pollution was discussed by S. Smith Griswold (Air Pollution Control, Los Angeles County) and Joseph R. Christian (St. Luke's Hospital, Chicago). Atmospheric inversion, a prerequisite for the development of high concentrations of harmful irritants, is obviously not subject to control. All other modes of control have to be fitted to the particular problems of the community, the source of emissions, their chemical nature, their concentration, and their effects, which may include simple nuisance value and economic loss.

JOHN S. CHAPMAN
University of Texas Southwestern Medical School, Dallas

Mollusks

Sensory, integrative, and effector aspects of the responses of marine gastropods, cephalopods, and bivalves to significant aspects of environment were emphasized in a symposium on the Mollusca at the Zoological Society of London, 4–5 March 1964.

In the first session on bivalves, P. Korringa (Netherlands Institute for Fishery Investigation) emphasized the decisions required of the oyster larva at the end of its free-swimming stage. The larva tests a substrate for suitability by crawling over it with the foot, and may make temporary byssal attachments. However, once an attachment is made, the decision to affix permanently is irrevocable for the cement gland secretes its adhesive only once. Several environmental factors are unimportant to this decision, among them temperature, light, attitude of substrate and its color. However, currents play an important role in transport and physical-chemical properties of the surface provide relevant sensory information. The size of the object is also important.

Sedentary adults are characteristic of the class Bivalvia, and the larval stages are important in maintaining species distributions. However, K. W. Ockelmann (Marine Biological Laboratory, Helsingør, Denmark) reported on evolutionary tendencies in response to the conflicting selective pressures for species dispersal and for protection of eggs and developing young. Absence of an endogenous dispersal mechanism does not necessarily indicate a restricted distribution. Some relatives of mussels may be distributed primarily by the marine plants to which their juveniles are attached. The main factors determining type of development and mode of dispersal in marine bivalves appear to be food conditions, water movements, and availability of substrates appropriate to the habits of the individual species.

Bivalves of commercial importance continue to interest biologists. A. Ansell (University of Southampton) and D. A. Hancock (Fisheries Laboratory, Burnham-on-Crouch) discussed the particularly challenging stages of early life history. Ansell described seasonal biochemical changes occurring in the introduced American clam, *Venus mercenaria.* Successful reproduction has occurred in colonies at Southampton but not elsewhere in Britain. Ansell explained that temperatures above 18°C, required for spawning, occur in Southampton Water because of the warming of sea water used in industrial cooling systems. In discussing the edible cockle, *Cardium edule*, Hancock showed that an inverse correlation exists between the success of larval spatfall and the density of the adult population even though space for recruits seems to be available. The highest densities of young cockles are most likely to occur when a warm summer induces successful reproduction by adults remaining after a severe winter has reduced adult populations.

C. M. Yonge (University of Glasgow) and T. H. J. Gilmour (University of Exeter) dealt with functional morphology of bivalves. Yonge discussed general changes of form which enabled primitive bivalves to exploit soft sediments. Such changes in habitat subject animals to novel selective forces favoring further morphological changes. As a specialized example, Gilmour showed that the reduction of the anterior regions of the mantle cavity in some bivalves increases the strength of water currents leaving the oral grooves. These intensified currents, generated by the beating of cilia of the ctenidia, palps, and lips, are prevented from interfering with the passage of food toward the mouth by a complicated lip apparatus.

Gastropods are in general more active animals, and their responses are often more apparent and easier to study. G. E. Newell (Queen Mary College, London) described in detail the functional morphology of the complex eye of the intertidal snail, *Littorina.* Sun orientation and form vision are structurally possible and necessary to explain such behavior. Supporting evidence for form vision, as a requisite for the observed orientation on the shore, was presented by F. Evans (Dove Marine Laboratory, Cullercoats). The establishment of zonation by *Littorina* was shown by his experiments, in which he used tanks with manipulated artificial topography, tide, and light-dark cycles.

Various aspects of the feeding biology of gastropods were discussed. An ingenious approach to the difficult problem of the nature of the food of deposit feeders was reported by R. C. Newell (Westfield College, London). From measurements of carbon and nitrogen removal from test foods of varying composition by the snail, *Hydrobia,* Newell tentatively concludes that microorganisms are much more important as food than the organic debris of fine sediments. The latter are an additional link in the food chain and provide nutrient and surfaces essential for the bacteria.

E. H. Smith (Marine Station, Millport) discussed his comparative study of the proboscis of carnivorous gastropods of the suborder Toxoglossa. A single radula tooth is moved to the tip of the proboscis and injected with a paralyzing venom into the prey. The morphology and functioning of the feeding mechanism is remarkably similar to that of the most specialized Toxoglossa, *Conus,* and appears to have evolved mainly in more primitive members of the group. The feeding behavior of *Conus* was reviewed by A. J. Kohn (University of Washington) who emphasized ecological and evolutionary implications. A direct correlation has been found between food specialization and *Conus* species diversity. Where the latter is high, each common species feeds primarily on a different species or higher taxon of food organisms. This specialization thus aids in maintaining populations of many closely related sympatric species.

In a paper entitled "Taxonomy and distribution of the subspecies of *Littorina saxatilis*," B. L. James (University College of Swansea) showed correlations between morphological variation, habitat, and distribution.