

Similar correlations were found in studies of cuticular permeability-lipid composition in desert tenebrionid beetles. Total surface lipids extracted from *E. armata* throughout the year ranged from 0.10 to 0.28% of their fresh weight. Hydrocarbons were most abundant, but percentage values varied depending upon the solvent used to extract the lipids (for example, chloroform:methanol removed more total lipids than did hexane). Hydrocarbons comprised over 25 components, all saturated, containing 26 to 44 carbon atoms. Branched alkanes accounted for over 92% of the total hydrocarbons, and were responsible for all components having chain lengths greater than 34 carbon atoms. Summer beetles and winter beetles acclimated to 35°C for periods of 5 and 10 weeks exhibited higher quantities of hydrocarbons and a higher percentage of long-chain components than did winter beetles in nature or appropriate controls.

The potential adaptive significance of this epicuticular lipid composition was examined further by comparing results for *E. armata* with similar analyses performed on four other sympatric species and correlating these data with the species' cuticular permeability (see the table). Cuticular transpiration increased linearly between 25 and 40°C in all species, but remained low in comparison to more mesic beetle species. Hydrocarbons accounted for over 90% of the total lipids in each species; they were completely saturated with odd-numbered chains containing from 25 to 33 carbon atoms predominating. The percentage of straight-chain hydrocarbons ranged from 7.7% in *E. armata* to 78.5% in *Cryptoglossa verrucosa*, the least permeable tenebrionid species. *Cryptoglossa verrucosa* was further characterized by having predominantly long-chain saturated *n*-alkanes, which should contribute to an effective cuticular water barrier.

**Cuticle fine structure.** Little information is available on the synthesis, transport, and deposition of these lipids in desert arthropods. A recently completed ultrastructural study of sclerite and intersegmental cuticle in *H. arizonensis* indicated that lipids are most likely distributed throughout the epicuticle and may be bound to protein or carbohydrate compounds. The latter belief is based on the failure of organic solvents to produce significant changes in the morphology of the epicuticular sublayers. *Cryptoglossa verrucosa* secretes waxes as amorphous blobs that reach the surface through narrow cylinders that open in the center of raised tubercles. At low humidities, the wax plug breaks into a fine basketlike network of filaments that completely covers the surface, giving the species a "blue" appearance. This morphological arrangement of surface waxes is potentially adaptive in that it both increases reflectance of solar radiation when the species is diurnally active and lengthens the diffusion pathway for water.

**Summary.** The majority of the adaptations exhibited by most desert scorpions and beetles are techniques for conserving rather than regaining water. Furthermore, most of these adaptations are not unique to desert arthropods, but are more highly developed and efficiently utilized in desert species than in their nondesert counterparts. Further studies on the adaptational biology of these groups will likely support these evolutionary trends.

For background information see ARACHNID BEETLE: COLEOPTERA in the McGraw-Hill Encyclopedia of Science and Technology.

[NEIL F. HADLEY]

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## Pipeline

Although past growth in pipeline transport in the Western world has been slow and steady, inflation and the recent concern about energy supplies have caused a surge of interest in hydraulic transport, especially for coal. In the United States the lack of Federal legislation for eminent domain has hampered progress, but 10 states now have such laws.

Plans for three new overland coal slurry pipelines in the United States and Europe were announced, and a large pipeline in Brazil for phosphate is scheduled to begin operation in 1978. Two new research pipeline facilities in England and West Germany were commissioned in 1978, one research pipeline facility is under construction, and another is planned, in the United States. One full-scale hydraulic haulage system in an underground coal mine has begun operations in West Germany, and another is under construction in the United States.

Three concepts for reducing or eliminating the problem of limited water supply received attention in 1978. Transporting coal in methanol is a new concept, and although coal in oil and in stabilized suspension are not new approaches, they are being considered.

**Overland pipelines.** The increase in construction of overland pipelines in the Western world has been steady over the past 4 decades, and the announced plans for additional construction indicates a spectacular increase in the next decade, as shown in Table 1. Nine of the pipelines planned for the 1980s are for transporting coal directly to electric generating plants, and five are for iron ore concentrates. The remaining two are for phosphate. The total capacity of the planned coal slurry pipelines is expected to be over  $1.3 \times 10^6$  short tons ( $1.2 \times 10^6$  metric tons) per year and  $2.1 \times 10^7$  tons ( $1.9 \times 10^7$  metric tons) per year for the iron ore concentrate pipelines. The coal pipeline figures reflect the effect of the increased concern about energy supply in the past few years. Table 2 shows the planned pipelines announced in 1978.

The seven coal slurry pipelines in the United States which are in various stages of planning are

Table 1. Overland pipelines in Western world

Decade	Number of pipelines	Annual capacity, 10 <sup>6</sup> short tons (10 <sup>6</sup> metric tons)	Total length, mi (km)
1940s	1	0.4 (0.36)	17 (27)
1950s	3	2.3 (2.1)	186 (298)
1960s	3	4.6 (4.2)	154 (246)
1970s	9	18.6 (16.9)	687 (1106)
1980s*	16	160.7 (145.8)	8235 (13,252)

\*Planned

Table 2. Coal slurry pipelines planned in 1978

Location	Length, mi (km)	Diameter, in. (mm)	Annual capacity, 10 <sup>6</sup> short tons (10 <sup>6</sup> metric tons)
Kentucky to Florida	1500-1800 (2414-2897)	28-48 (711-1219)	15-45 (14-41)
Silesia, Poland, to Trieste, Italy	400 (644)	22 (559)	5 (4.5)
Energy Transportation Systems, Inc. (addition)	400 (644)	38 (965)	N.S.*

\*N.S. = not specified.

being delayed by the need for uncontested water supplies, by the need for legislation granting the right of eminent domain, and by the lack of firm long-term coal contracts.

Federal legislation concerning eminent domain has been under consideration since 1974, but opposition by railroad companies and western states with limited water supply has delayed it. A study completed in 1978 by the Office of Technology Assessment concluded that there will be plenty of transport business for both railroads and pipelines and that delivery costs will be roughly comparable. Pipelines, however, were credited with being more reliable, less labor-intensive, and more acceptable esthetically and environmentally.

In July 1978 the House of Representatives voted to reject the most recent bill, H.R. 1609; however, other versions are certain to be introduced in the future. Presently, 10 states have legislation that either grants eminent domain to slurry pipelines or that can be interpreted as granting such rights. At least two other states are currently considering such legislation.

The considerations discussed above apply to overland pipelines in the United States for other transported solids as well, but none was announced in 1978. Overland pipelines in other countries have not experienced route acquisition problems because other national governments usually have greater control over property than in the United States.

**Coarse-particle pipelines.** Over the past few years experimental work in the study of coarse particles (especially coal) in large pipes has intensified, culminating in 1978 with the commissioning of two large research facilities in England and in West Germany. A large facility is nearing completion in the United States, and a moderate-size one is planned.

Also during 1978, one full-scale coal mine hoisting system began operation in West Germany, and a coal mine haulage and hoisting system is under construction in the United States. All of these facilities have pipe sizes of at least 6 in. (15 cm) and are designed to handle materials, primarily raw coal (uncleaned coal which contains rock and clay), with maximum particle sizes of 2 to 4 in. (5 to 10 cm). Table 3 lists these new facilities.

Aside from dredging, the great bulk of existing production systems that handle large particles are designed for the hoisting of raw coal from the underground workings to the surface. Research in the Eastern bloc nations has been in progress for many years, but reports of findings have been slow to reach the Western nations. The Soviet Union has several coarse coal haulage systems in operation, as does the People's Republic of China.

A number of articles on the transport of coarse-particle phosphates have been published, but a rough approach is used because of the lack of engineering data. The use of dredging is extensive, and sufficient work has been carried out to create a

Table 3. New coarse-particle facilities

Organization	Location	Pipe diameter, in. (mm) <sup>a</sup>	Circuit length, ft (m)	Vertical lift, ft (m) <sup>b</sup>
British Hydrodynamics Research Association Fluid Engineering	Cranfield,	6 (150)	140 (43)	0
	Bedford County, England	8 (205)	373 (114)	43 (13)
		10 (255)	165 (50)	0
Steinkohlenbergbauverein	Essen, West Germany	10 (255)	690 (210)	13 (4)
		10 (255) <sup>c</sup>	150 (46)	13 (4)
		14 (353) <sup>d</sup>	N.S. <sup>e</sup>	N.S. <sup>e</sup>
U.S. Department of Energy	Pittsburgh, PA	6 (150)	720 (220)	90 (27)
		12 (305)	760 (232)	150 (46)
		18 (430)	790 (241)	150 (46)
State of Kentucky and University of Kentucky	Lexington, KY	6 (150)	600 (183)	-
Ruhrkohle Aktiengesell- schaft, Hansa Mine	Dortmund,	10 (255)	10,000 (3050)	2790 (850)
	West Germany	10 (255) <sup>g</sup>	12,300 (3750)	
Continental Oil Co./ Consolidation Coal Co. Loveridge Mine	West Virginia	8 (205)	f	0
		14 (333)	f	0
		12 (305)	13,500 (4115)	900 (274)

<sup>a</sup>Nominal pipe size.<sup>b</sup>Included in circuit length.<sup>c</sup>Alternate pipeline.<sup>d</sup>Future.<sup>e</sup>N.S. = not specified.<sup>f</sup>Variable.

large separate field of information. Deep-ocean mining is relatively new, and many of the problems of lifting minerals from depths as great as 15,000 ft (4575 m) have not been solved. Some academic studies have been published, but the bulk of the practical work has been performed by private industry and is considered proprietary.

**Theoretical and experimental work.** While the hydraulic transport of fine particles is fairly well understood, there have been no recent breakthroughs in the theory of coarse-particle transport. Until good reliable data are generated in test facilities, the approach to a theoretical solution will not be apparent. For many years researchers have unsuccessfully attempted to solve the problem by working on test facilities having pipelines of small diameter and length. Similarly, studies with low concentrations of solids (less than 20% by volume) have not been adequate to predict the performance of two-phase transport for higher concentrations. It is only when the experimental work is done at or near full-scale that results are considered to be reliable.

**New concepts.** Coal slurry is usually a mixture of coal and water; however, other fluids have been proposed as transport media. One proposal is to use part of the coal to produce methanol ( $\text{CH}_3\text{OH}$ ); the rest could be mixed with the methanol and transported as a slurry. Water is not needed, and the mixture could be burned directly. In addition, the mixture is reported to have better transport characteristics than a water-based slurry due to its having a gellike consistency until pump pressure is applied, when it flows with normal fluidity.

A concept which has been mentioned in the past is coal in oil. This process would avoid the problems of obtaining water at the origin and of disposing of it at the destination. Research is being carried out to develop a burner which could efficiently burn the mixture, thereby avoiding the separation problem. If separation problems can be solved, the pipeline could be used for two-commodity transportation.

A third concept which is under more intensive review is that of using a transport medium composed of water containing particles fine enough to remain suspended at very low flow rates. At a sufficiently high concentration of particles, larger and heavier particles can be supported in the flow. Tests have indicated that concentrations of solids can be as high as 75% without major transport problems.

For background information see COAL; PIPELINE in the McGraw-Hill Encyclopedia of Science and Technology. [ANTHONY J. MISCOE]

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## Plant disease control

Plants can be protected against disease by using procedures that are essentially identical to those used to immunize animals. Recent work of this type has been carried out with cucurbits.

**Immunization with *Colletotrichum lagenarium*.** J. Kuć and S. Richmond reported that infection of a cotyledon or first true leaf (leaf one) of cucumber with the fungus *Colletotrichum lagenarium* systemically protected tissue above (developed or not yet developed) against disease caused by the pathogen. Physical damage or chemical injury did not elicit protection. Susceptibility in this interaction is characterized by the formation of large but defined lesions. Since many such lesions may form and coalesce on the leaves, stems, and fruit of cucurbits, the growth of plants and their productivity, as well as the quality of fruit, are adversely affected. Nevertheless, the restricted size of individual lesions suggests the presence of a mechanism for resistance in susceptible plants. It would appear, therefore, that the defense mechanism against the disease in the unprotected plant either is elicited with insufficient magnitude or is expressed too late.

This systemically induced protection is manifest as a delay in symptom expression and a reduction in the number and size of lesions. Infection of leaf one of cucumber when the second true leaf was one-fourth to one-third expanded systemically protected plants for 4-5 weeks, at which time plants had 8-12 large leaves. A second, booster inoculation 3 weeks after the first extended the time of protection into the fruiting period. Protection was elicited by and effective against six isolates of the fungus and was evident with 20 susceptible cultivars and 6 cultivars which expressed some resistance to the pathogen. Resistance in these cultivars is expressed, as in systemic induced resistance, by a delay in symptom appearance and a reduction in the number and size of lesions. A single lesion on leaf one produced significant protection. Protection was evident on the second leaf 72-96 hr after inoculating leaf one. Excising leaf one 72-96 hr after inoculating leaf one did not reduce protection of leaf two. Leaf two was protected if excised 96-120 hr after leaf one was inoculated. Thus it is evident that it is not necessary for the inducer to be present once protection has been initiated and that protection continues to be expressed in all developing leaves for 4-5 weeks. It is also evident that the protected leaf need not be attached to the plant to maintain protection.

Caruso and Kuć reported that the pattern of protection in watermelon and muskmelon resembles that in cucumber. Infection of the cotyledons or first true leaf of four cultivars of watermelon and four cultivars of muskmelon with *C. lagenarium* systemically protected the plants from disease caused by subsequent infection with the pathogen. Plants remained protected 4 weeks after the protecting inoculation. Race 1, 2, and 3 of the fungus and a single lesion on leaf one elicited significant protection.

Extending their studies to the field, Caruso and Kuć found that, in three separate trials, cucumber plants were systemically protected against *C. la-*

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*Left. Calcite biocrystals decorating a triradiate spicule from a sea urchin embryo. The spicule, incubated in a solution of calcium chloride and sodium bicarbonate, acted as a seed for crystal growth.*

*Right. Scanning electron micrograph of skeletal spicule from Arbacia.*

*(From S. Inoué and K. Okazaki, Biocrystals, Sci. Amer., 236(4):82-95; copyright © 1977 by Scientific American, Inc.; all rights reserved)*

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