Table 1. A comparison of the coaxial cylinder data of Brundage on oxalate-stabilized whole blood (*3*) with our data for fresh, untreated whole blood, at equivalent hematocrits; cp, centipoise.

Hematocrit	Shear rate (sec^{-1})	Viscosity			
		Brundage		Present work	
		cp	A/B	cp	A/B
28	23 (A)	2.8	1.00	3.7	1.12
28	46 (B)	2.8		3.4	
44	23 (A)	6.0	1.00	8.4	1.15
44	46 (B)	6.0		7.3	
56	23 (A)	16.6	1.12	12.6	1.38
56	46 (B)	14.8		9.1	

rate, and that the instrument value agrees precisely with the stated viscosity.

A cone and plate viscometer is particularly appropriate for the study of blood rheology, because a small sample can be rapidly analyzed to obtain unequivocal and absolute values for shear stress and therefore viscosity for every value of shear rate imposed on the sample. The validity and derivation of the shear stress and shear rate with this type of instrument have been given elsewhere (*6*). In the present studies the full-scale deflection of the viscometer spring equaled 673.7 dy-cm, while the cone had an angle of 1°33′ and a radius of 2.4 cm. The four shear rates recorded, therefore, were 23.18, 46.36, 115.92, and 231.84 sec^{-1}.

In Fig. 1 (top) the curves of apparent viscosity of whole blood versus shear rate are presented for three hematocrit levels as indicated. The characteristic shear thinning type of curve for pseudoplastic fluids is apparent. The higher the hematocrit the more pronounced is the rise of apparent viscosity at low rates of shear. Values of serum protein and cholesterol were normal in all samples studied. To clarify the role of anticoagulants, the coaxial cylinder data of Brundage (*3*) on oxalate-stabilized whole blood are compared with our data (Table 1) for fresh, untreated whole blood, at equivalent hematocrits.

There appears to be a consistent trend in these data of substantially greater shear dependence of viscosity in fresh whole blood as compared to oxalate-treated whole blood, as indicated by the viscosity values at rates of 23 sec^{-1}, (A), and 46 sec^{-1}, (B).

In Fig. 1 (bottom) are shown curves of viscosity of plasma versus shear rate. The three curves represent values obtained with untreated plasma, and plasma obtained from anticoagulant-treated whole blood. All three were obtained from the same blood sample. It is evident that below approximately 50 sec^{-1} shear rate, the curvature (and thus the shear rate dependence of viscosity) of fresh plasma is greater than that of heparinized or oxalate-derived plasma.

In respect to plasma, Brundage (*3*) working on oxalate-treated samples found no difference in viscosity between a 2.2 sec^{-1} and a 5.14 sec^{-1} shear rate, which is in essential agreement with the findings reported here. Bingham (*7*) makes no mention of having observed non-Newtonian viscosity in plasma in which the content of oxalate-treated fibrinogen was varied. In the light of his pioneering work in non-Newtonian rheology, it is unlikely that non-Newtonian viscosity effects would have escaped his notice, had they existed.

The above data seem clearly to indicate that more attention should be focused on the viscosity of fresh blood and fresh plasma, even though it is experimentally difficult, in order to detect rheological characteristics at different rates of shear.

The consequences of shear rate dependence of viscosity on hemodynamics may prove to be profound. For example, in the microcirculation, the procession of erythrocytes in "single file" through capillaries (*8*) may be strongly influenced by the high shear rate dependence of plasma viscosity, in that next to the wall where the shear rate is highest, the plasma viscosity would be low, whereas between any two erythrocytes where the shear rate is very low, the viscosity would be high. Such a situation would tend to stabilize single-file procession and minimize tumbling or rotation of the erythrocytes. This shear rate dependence of blood and plasma viscosity does not necessarily support or contradict the concepts of "plasma skimming" or "axial streaming" (*9*) as applied to flow in the smaller vessels. Continuing research is aimed at elucidating the effects of the shear rate dependence of viscosity upon these and related phenomena.

Freshly drawn whole blood and fresh plasma separated from the red cells show a high degree of shear rate dependence of viscosity, whereas the addition of oxalate or heparin reduces the degree of shear rate dependence of viscosity in whole blood and causes it virtually to vanish in plasma. The shear rate dependence of viscosity in whole blood, especially in regard to movement of erythrocytes through arterioles, capillaries, and venules, would appear therefore to be a critical factor in the dynamics of blood flow of the microcirculation.

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Faunal Remains on an Antarctic Ice Shelf

Abstract. Fishes and benthic invertebrates discovered frozen *in situ* and exposed at the ablation surface of the McMurdo ice shelf provide evidence both for the occurrence of a fauna, including large fishes, under the permanent ice shelf and for Debenham's hypothesis of the nourishment of an ice shelf by the freezing of sea water on its bottom.

On 8 November 1960 we found the remains of upwards of 50 partially decomposed fish and the remains of several kinds of benthic invertebrates on the surface of the floating ice shelf in McMurdo Sound, Antarctica (Fig. 1). The remains were scattered over a small area some 2 km from the ice front near the easternmost of the Dailey Island group (77° 52′ S, 165° 18′ E). The ice shelf is probably more than 30 m thick in this area, and the surface is at least 3 to 5 m above sea level.

The largest intact fish measured 142 cm over-all. Some detached heads appear to have come from still larger fish. Numerous pelecypods, gastropods, brachiopods, siliceous sponges, and anthozoan corals were also found on the ice surface. Even the fragile invertebrates were well preserved, and, in the case of some sponges and corals, they were still attached to rocks that presumably came with them from the sea floor.

The significance of the find is twofold: first, the fish are larger than any yet reported from the Ross Sea and McMurdo Sound; second, the fish with the benthic sessile invertebrates could scarcely have reached this place alive, the only possible access from the sea being the tidal cracks in the ice bordering the nearby island. Thus there is reason to believe that a well-developed fauna exists under the permanent ice shelf.

Published information on fishes from the Ross Sea and McMurdo Sound pertains to much smaller specimens, usually not longer than about 30 cm. Remains of somewhat larger fishes have been regularly observed after regurgitation by Weddell seals. A large headless fish was harpooned along with a seal in the sea during the National Antarctic Expedition (1901–04) which was quartered on nearby Ross Island. This specimen, which was 112 cm long without the head, was identified as a nototheniid, *Notothenia* sp. (*1*). The specimens observed by us on the ice shelf appear to be members of at least two genera of Nototheniidae, the most common family of antarctic fishes.

Debenham (*2*) reported finding the headless remains of a somewhat smaller fish on the ice shelf in the same area during the British (Terra Nova) Antarctic Expedition of 1910–13. He also reported finding perfectly preserved sponges and corals on the ice surface. He suggested that these might have been trapped in the ice by freezing when the bottom of the ice shelf touched the sea floor, and then were brought slowly to the top by the progressive melting of the upper surface while new ice formed at the bottom.

On the basis of evidence available to him, Debenham concluded that the ice shelf was nourished principally by the freezing of sea water on its bottom surface, and that the main body of the Ross Ice Shelf (5.18×10^5 km^2) might be nourished in a similar manner. Though it is now generally believed that the main body of the Ross Ice Shelf is nourished principally by the accumulation of snow on its upper surface, the finding of marine fauna apparently preserved for hundreds of years in the ice would lend support to Debenham's hypothesis, with respect to the McMurdo ice shelf where there is definite evidence of considerable surface melting. This method of nourishment of a permanent floating ice sheet of con-

Fig. 1. McMurdo ice shelf near one of the Dailey Islands showing ablation surface. Dark surface area is wind-blown volcanic debris. Fish are indicated by arrows. [National Science Foundation photograph by R. J. Litell]

siderable area and thickness would be unique, the only known parallel being the small ice shelf off the north coast of Ellesmere Island in the arctic. Accordingly, we have taken samples of vertebrae and flesh from the newly found fish for carbon-14 dating, together with several specimens for taxonomic identification. The tentative radiocarbon date appears to be up to 1100 years (*3*, *4*).

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New Approach to Immunization against Schistosoma japonicum

Abstract. Previous inoculation of rhesus monkeys with cercariae of the nonhuman strain of *Schistosoma japonicum* proved to give a rather strong protection against a subsequent challenge with its human strain.

Investigators (*1*) have indicated that no definite resistance to second infection in schistosomiasis is present until the worms causing the primary infection have matured. It is probable, therefore, that the most important immunizing antigens are connected with schistosome eggs in the host. As the essential role in pathogenesis of schistosomiasis is ascribed to the parasite's eggs, it is regrettable to think that the immunity in schistosomiasis was produced by the reactions of an enormous number of detrimental eggs in the host's essential organs.

We have reported (*2*) that in *Schistosoma japonicum* there is a nonhuman strain which will naturally terminate its infection in the schistosomula stage in man, producing no important harmful effect during the course of infection. It will be of interest to investigate whether inoculations of the nonhuman strain of *S. japonicum* will produce immunity against the infection of its human strain. Also, it has been reported (*3*) that the rhesus monkey, *Macaca mulatta,* like man, is not susceptible to infection of the nonhuman strain of *Schistosoma japonicum,* although it is susceptible to the infection of the other human strains. Thus an immunization study was considered possible in rhesus monkeys without using human volunteers.

In our experiments, the Formosan strain of *S. japonicum* was used as the nonhuman strain and the Japanese strain as a human strain. Eleven monkeys were first inoculated by the cutaneous route with cercariae of the Formosan strain and then challenged with cercariae of the Japanese strain. Four monkeys were used as control animals which were inoculated only with the Japanese strain. While the number of cercariae of the Formosan strain given to each monkey varied, the number of the cercariae of the Japanese strain was always 200 males and 200 females for each monkey. Beginning from the 30th day of infection, the stools of each monkey were examined daily by the sedimentation method. After schistosome eggs were found in the stool, daily egg counts were followed for the entire patent period. As the maximum number of eggs per gram of stool per day during the patent period and the mean number of eggs of the first 30 days usually represent satisfactorily the intensity of infection of nonimmunized and immunized rhesus monkeys infected with *S. japonicum,* they were used as bases for the comparison in this paper (Table 1).

Table 1. Number of eggs of *Schistosoma japonicum* in the stools of immunized and nonimmunized monkeys.

Monkey No.	Inoculation					Eggs/gram per stool/day	
	Immunizing		Challenge				
	No.	Cercariae (No.)	Cercariae (No.)	Days after immunizing inoculation		Maximum	Mean, first 30 days
				1st	Last		
			Immunized monkeys				
9	2	3,400	400	41	14	58	4
10	2	3,073	400	39	21	18	4
1	3	1,800	400	283	14	0	0
8	3	2,000	400	41	14	1,634	308
11	3	2,000	400	41	14	130	25
49	3	5,000	400	74	31	146	45
42	4	9,000	400	141	30	36	8
14	5	5,600	400	67	4	450	57
15	5	5,450	400	67	4	548	58
13	7	12,515	400	261	31	624	140
5	8	3,600	400	148	21	616	114
			Nonimmunized monkeys				
32			400			14,790	1,220
31			400			21,840	4,712
30			400			69,120	6,693
55			400			88,400	46,036

In the immunized monkeys, the maximum number of eggs per gram of stool per day in the patent period varied from 0 to 1634, while in the nonimmunized it varied from 14,790 to 88,400. The mean number of eggs of the first 30 days of the patent period in the immunized monkeys varied from 0 to 308, while in the nonimmunized monkeys the difference was from 1220 to 46,035. From these results, it can be concluded that previous inoculations of rhesus monkeys with the cercariae of the nonhuman strain of *S. japonicum* gave a rather strong protection against a subsequent challenge with its human strain. It is hoped that, by a proper adjustment of the timing, dosage, and number of inoculations of the immunizing cercariae, a state of absolute resistance to the challenge infection might be reached. The immunization procedure introduced here may hopefully lead to the development of an effective way to combat schistosomiasis japonica (*4*).

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