one that explicitly violates such conditions. For this case our equation 4 would predict that no steady state is possible, the compartment concentration continuously increasing toward infinity. Actually, however, back-diffusion must finally take over as a removal mechanism, and an unusual type of steady state results where convection of solute into the compartment is exactly counterbalanced by back-diffusion outward through the same membrane. Under this set of conditions the overall steady-state sieving characteristics will, of course, be those intrinsic to membrane M rather than membrane N.

Finally, we do believe that we have called into question certain present-day concepts relating to steady-state sieving. There are two views relating to this process which differ from one another in a quite fundamental way. According to the first view, sieving is regarded as taking place by an exclusion process: there is a dispersion of pore sizes with uniform particle sizes, or a dispersion of particle sizes with uniform pore sizes, or oddly shaped particles or pores (or both) so that some sort of lock-and-key arrangement involving proper orientation is required in order for solute to cross the membrane. According to the second view, the interior of the membrane is an extended convoluted surface that may interact through the thickness of the membrane more strongly with one species passing through it than with another. We question the validity of this second view for the steady state, since it implies that more of one species than another is continually accumulating in the membrane as long as sieving goes on, unless some mechanism (as yet undefined, to our knowledge) acts to discharge the accumulating solute back into the feed solution. Incidentally, we did not propose the series array model as a valid model of a sieving membrane with the membranes after the first serving as analogs for frictional interactions, but rather to illustrate that a removal mechanism must be present to remove solute from the site at which it is accumulating in order for effective sieving to occur. With this in mind, let us analyze a simple presumed frictional model for sieving in the form of a capillary, the walls of which retard the passage of solute more strongly than solvent. When a flow of solution is generated in this capillary, relatively less solute than solvent emerges. This hypothesis implies continual accumulation of solute within the capillary unless in the steady state some mechanism is available which either (i) transports solute from inside the capillary back into the feed solution or (ii) prevents a portion of the solute from entering the capillary. For the first possibility one might attempt to postulate a concentration gradient. But since the solution entering the capillary has a higher concentration than that emerging, the orientation of a presumed gradient is the opposite of what is required. For the second possibility we must ask ourselves what force could be present at the capillary entrance that could be transmitted from frictional events inside the capillary to the solute molecules but not to the solvent molecules (both electrically neutral). This possibility would appear to require either some action at a distance or some contact force involving such enormous concentrations of solute that the molecules in the capillary are in virtual direct contact with one another. The first mechanism is unknown, and the second seems highly implausible. Thus sieving on the basis of continuous point-to-point interaction with the interior of a membrane does not seem possible in the steady state, but can only be a transient phenomenon, as in the example of chromatography, and will disappear as the interaction sites become saturated. In fact, a main point of our report, which seems somehow to have become lost, was that this particular attempt to visualize the nature of sieving in concrete physical terms cannot be valid in a steady state. The use of the constraint of the steady state is not a trivial exercise in semantics (although the conclusions appear obvious in retrospect), but rather is a powerful tool that can be used in a very simple way to test theoretical models of the sieving process.

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1. E. H. Bresler, R. P. Wendt, E. A. Mason, *Science* **172**, 858 (1971).

18 October 1971; revised 27 December 1971

Boconó Fault, Venezuelan Andes

Preliminary study of glacial stratigraphy in the valley of Rio Santo Domingo, State of Mérida, Venezuela, leads us to comment on the conclusion reached by Schubert and Sifontes (*1*) that right-lateral, strike-slip movement along the Boconó fault has averaged 0.66 cm/year during the last 10,700 years.

The width of the area mapped by Schubert and Sifontes adjacent to the fault [figure 1 in (*1*); compare Fig. 1] is not sufficient either to establish the crest of the lateral moraine or to project its apparent curvature into the fault zone. This can be demonstrated on their map by restoring the two segments of the Victoria lateral moraine to the prefault configuration; the fault apparently cuts the moraine at a point of abrupt change in curvature, an unlikely coincidence. Furthermore, projection of the *north* side of the Victoria moraine across the fault zone would yield a significantly larger measure of apparent displacement. The citation of the computed average of 66 m (*1*, p. 68) to two significant figures implies an accuracy unlikely to be achieved by the method used and thus represents no improvement on the previous estimate of 80 to 100 m (*2*).

The terraces within the Zerpa lateral moraine described by Schubert and Sifontes (*1*, p. 68) at 20 to 25 m and at 6 to 10 m above the bed of the creek (see Fig. 1) were deposited within the morainal loop in the Zerpa valley at times when the stream draining the valley crossed the moraine at altitudes higher than the modern outlet. The outlet was lowered at least twice, either by faulting or by erosion, preserving the terraces as traces of two higher long profiles. The higher terrace, which is well developed upstream of the fault, ends near the point where the fault cuts across the morainal loop; the lower terrace is downthrown by 50 to 100 cm north of the fault. We do not dispute that incision ultimately was responsible for preserving the two terraces, but it seems probable that vertical movement on the fault induced the incision. Displacement occurred at least twice after emplacement of the moraine; in each case, the sense of movement was down to the north. Schubert and Sifontes dismissed the terraces as due to "probable uplift, because these features are common throughout the cordillera" (*1*, p. 68).

The elevated dry creek bed north of the fault in the Zerpa valley was cited as proof that the block north of the fault was upthrown (*1*, p. 68); Schubert and Sifontes did not consider the probability that the dry valley was left hanging by incision of the creek bed through which drainage was diverted after faulting occurred. If diversion is assumed to have occurred at the time of earlier (and greater) vertical movement along the fault, subtraction of 14 m [height of the dry valley above the stream bed (*1*, p. 68)] from 20 to 25 m [height of the higher terrace (*1*, p. 68)] indicates that the north side of the fault was downthrown a minimum of 6 to 11 m.

To calculate an apparent rate of movement along the Boconó fault, Schubert and Sifontes cited the age of 8100 B.C. proposed by van der Hammen and González (*3*, p. 312) for the time of transition from Würm "Late-Glacial" to Holocene in the Sabana de Bogotá, Colombia, and assumed that this age could be applied to the Venezuelan Andes as an approximation of the time of retreat of Andean glaciers from their terminal positions.

The comparison between the climatic setting at Bogotá and in the upper Santo Domingo River valley is valid in that each site is at a high altitude and receives drainage from higher terrain. The two localities fall, however, in very different climatic belts. Bogotá, at 4°30′N, receives annually 600 to 900 mm of rainfall, chiefly during rainy seasons in spring and fall (*3*, p. 269). The Santo Domingo valley, at 8°45′N, receives approximately 1100 mm of rainfall per year [figure 1 in (*4*)], much of it during the summer when the intertropical convergence is close to its most northerly position. Direct temperature observations at Mucubají, a station 4 km west of the two moraines, indicate a mean temperature of 4.7°C for April to September 1968 [table V in (*4*)]; from measurements on the Sabana de Bogotá (*3*, p. 269; *5*), we calculate a mean temperature of ± 14.2°C for April to September and a mean temperature of ± 14.5°C for a typical year.

It has yet to be demonstrated that climatic changes at the margin of the intertropical convergence need be in phase with changes closer to its center; indeed, almost nothing is known of the chronology of climatic change at latitudes of 8°45′ (north or south) anywhere in South America. In the absence of local chronology, therefore, proposed correlation of climatic events in the Venezuelan Andes with those reported from higher or lower latitudes should not be accepted uncritically.

An age of 5470 ± 80 ^{14}C years B.P. (*1*, p. 68), obtained by analysis of a "soil sample" (IVIC-722) collected at a depth of "1 m below the present valley surface," was presented in support of extension of the Bogotá chronology to the latitude of the Santo Domingo valley. Neither the location, the composition, nor the stratigraphic relation of the sample to glacial or fluvial deposits was specified.

The sample is described in *Radiocarbon* (*6*) as a "soil sample from fluvial terrace, 1 m below surface . . . assoc[iated] with gravel and sand of glacial origin." Radiocarbon activity was measured in "2.9% non-carbonate, non-rootlet carbon." If the carbon material was in isotopic equilibrium with the atmospheric reservoir at the time of the implied fluvial sedimentation, then the age can be interpreted as a minimum age of retreat of the glacier terminus upvalley from the point where the sample was collected, an interpretation consistent with the correlation with Bogotá. If, however, the carbon is of the same "glacial origin" as the gravel and sand with which it was associated in the "fluvial terrace" (*6*), its age can be interpreted only as a time at which ice was present somewhere in the valley. If the "fluvial terrace" (*6*) is interpreted as an erosional feature developed on earlier glacial sediment, then the age of the sample represents a time when the glacier margin stood at least as far downvalley as the sample site, a chronology not consistent with that of Bogotá. If the carbon is interpreted as contemporaneous with the beginning of the soil-forming activity that produced the meter of soil over the sample (*1*, p. 68; *6*), then the pedogenic agent envisioned must be one capable of penetrating 1 m of fluvial or glacial sediment, or both, in 4580 ^{14}C years (the difference between the age of the sample and the proposed age of the moraine, corrected to citation in years before 1950).

Since radiocarbon sample IVIC-722 is critical to support the contention of Schubert and Sifontes that the chronology from Bogotá applies at this latitude, we feel that a more comprehensive description of the nature of the dated material and the context of its occurrence should have been included in order to support their conclusions.

The value of 0.66 cm/year offered as a measure of the rate of postglacial strike-slip displacement along the Boconó fault (*1*) is based on unsupported assumptions; geomorphic data cited in support of the measured rate

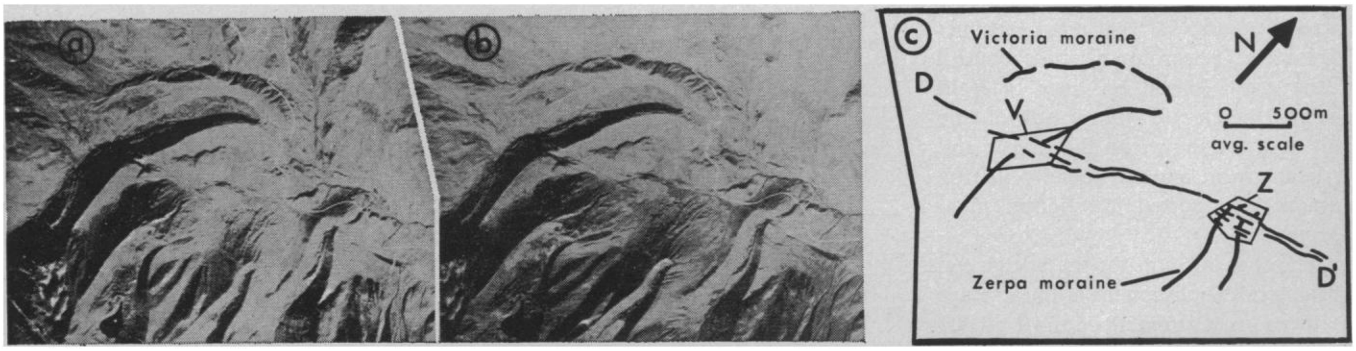

Fig. 1. (a and b) Stereopair of glacial moraines in the valley of Rio Santo Domingo [reproduced with permission of the Ministerio de Minas e Hidrocarburos, Caracas, Venezuela]. (c) Sketch of photograph b. The Victoria and Zerpa moraines are indicated by heavy lines; *D–D′* is the line (locally a narrow zone) of topography disturbed by late displacement along the Boconó fault. The polygons labeled *V* and *Z* represent approximately the areas mapped in detail by Schubert and Sifontes [figure 1 in (*1*)].

indicate that the late history of movement along the Boconó fault was more complex than the proposed conclusion implies.

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References and Notes

1. C. Schubert and R. S. Sifontes, *Science* **170**, 66 (1970).
2. E. Rod, *Amer. Assoc. Petrol. Geol. Bull.* **40**, 465 (1956); ———, C. Jefferson, E. von der Osten, R. Mullen, *Bol. Inform. Asoc. Venez. Geol. Miner. Petrol.* **1**, 69 (1958).
3. Th. van der Hammen and E. González, *Leidse Geol. Meded.* **25**, 261 (1960).
4. J. Nieto and J. M. Arroyo, trabajo especial de grado, Facultad de Ciencias Forestales, Universidad de los Andes, Escuela de Ingeniería Forestal, Mérida, Venezuela (1968).
5. R. C. Eidt, *Rev. Acad. Colomb. Cienc. Exactas Fis. Nat.* **8**, 492 (1952).
6. *Radiocarbon* **13**, 43 (1971).
7. We thank the Ministerio de Minas e Hidrocarburos, Caracas, Venezuela, for support of the field investigation. R. Shagam read the manuscript and offered helpful advice.
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16 February 1971; revised 29 April 1971

Giegengack and Grauch claim that the width of the areas mapped by us (*1*) is not sufficient to establish the crest of the lateral moraines, or to project the apparent curvature. Our maps [figure 1 in (*1*)] show an area across the moraines (north and south of the fault), from the valley floor within to the mountain flank outside the morainal loop. The crest is sharp and curves regularly, as can be seen very clearly in Giegengack and Grauch's figure. Incidentally, the strike-slip displacement shows quite well on their photographs and map, which were the basis for earlier measurements (*2*). The scale to which we had to reduce our maps prevented us from showing even more topographic details. The original maps had 1-m and, in some critical areas, 0.5-m contour intervals. To measure the displacement we projected the southern crest of the Victoria moraine across the fault, for two main reasons: (i) we had better topographic control of the crest (based on lines of sight reaching about 0.5 km south of the fault and not shown on the map); and (ii) data from another locality (Zerpa moraine) supported a shorter measurement.

Our value of 66 m for the postglacial right-lateral displacement is the average of three measurements on 1 : 1000 maps. On these maps we could confidently measure to an accuracy of 1 m. The value could, however, be rounded off to 70 m, which would not change the average rate of movement significantly (0.70 as compared with 0.66 cm/year). One of the main conclusions of our report (*1*) (namely, that the rate of strike-slip movement along the Boconó fault is a reasonable one) remains unchanged.

The formation of the terraces within the Zerpa morainal loop is probably evidence of uplift, as stated both by us (*1*, p. 68) and by Giegengack and Grauch. However, it is difficult to separate the uplift due to relative vertical movement along the Boconó fault from that due to Quaternary raising of the cordillera. Another possibility, not considered before, is that the terraces may represent deposition under drier climate (*3*). Incision may be the effect of later, more humid conditions. Detailed work on the Quaternary stratigraphy of this region is necessary before the climatic chronology will be known.

If we assume, however, that uplift did originate the terraces, Giegengack and Grauch's arguments with respect to the relative vertical movement along the Boconó fault are plausible and represent a reasonable alternative to our arguments. We found no evidence of a 50- to 100-cm downthrow of the 6- to 10-m terrace north of the fault. To use Giegengack and Grauch's objections to our measurements with accuracies in the meter range, we doubt that such small displacements can be measured.

In support of their argument that the data of van der Hammen and Gonzáles (*4*) are not applicable in the Venezuelan Andes, Giegengack and Grauch use present-day mean annual rainfall and temperature. It is well known that in the tropics mean temperature is generally a function of elevation. When the temperature-elevation curve for the Sabana de Bogotá [figure 3 in (*4*)] is used, a mean annual temperature of about 7°C corresponds to the approximate elevation of the area under study (3500 m), in the upper Santo Domingo River valley. Because the Sabana de Bogotá is in the sheltered side of the Cordillera Oriental, it receives less rainfall than the upper Santo Domingo River valley, which is located in the eastern side of the Venezuelan Andes, is exposed to the seasonal winds, and is therefore more humid. Mean annual rainfall may vary within relatively wide limits; great local variations of climatic conditions in a mountain range are not rare. This is shown by the scanty mean rainfall data of the Santo Domingo and Mucuchíes areas, adjacent to the region under discussion. Santo Domingo (about 12 km northeast) has a mean annual rainfall of 1227 mm (*5*), whereas San Rafael de Mucuchíes (about 10 km southwest) records only 561 (*5*) to 650 mm (*6*). Similarly, in the Sabana de Bogotá region, there are localities with a maximum rainfall of 1390 mm (*4*, p. 270), considerably higher than that reported by Giegengack and Grauch. Higher average rainfall, with accompanying denser cloud cover, in the upper Santo Domingo River Valley accounts in part of its low mean annual temperature [4.4° to 5.6°C range recorded at the Mucubají station, approximately 2 km west of the Victoria moraine (*6*)]. In any case, Giegengack and Grauch's incomplete and arbitrarily selected present-day climatological data have little, if any, influence on the correlation of our Late Glacial data with that of the Sabana de Bogotá and other localities in the cordillera, because our correlation is based mainly on radiocarbon dates.

Moreover, the Colombian data (*4, 7*) indicate that climatological change during the Late Glacial for different regions in the Cordillera Oriental (4.5° to 6.8°N) are quite uniformly recorded in the deposits. These authors find good reason to correlate these climatological changes with those of Europe (*4*, pp. 307–308), over 30° of latitude farther north, and with other parts of the world (*8*). Lack of similar detailed data for the Sierra de Santo Domingo was our main reason for a preliminary correlation with the Colombian data; further work in the former will eventually produce a paleoclimatic sequence for it. Areas separated by only 2° of latitude can hardly be considered to lie in "different climatic belts," especially tropical mountainous areas.

Table 1. Radiocarbon dates of carbonaceous sediments from the Victoria moraine valley (based on a ^{14}C half-life of 5568 years) (*9, 10*).

Sample No.	Depth below surface (cm)	C (%)	^{14}C age (years before 1950)
	Profile 1		
IVIC-764	10–20	2.2	450 ± 70
IVIC-763	50–60	2.4	3920 ± 90
IVIC-762	80–90	0.98	5800 ± 80
	Profile 2		
IVIC-766	50–60	8.3	5360 ± 90
IVIC-767	70–80	8.7	5590 ± 100
IVIC-765	90–100	3.9	8790 ± 120

Nevertheless, Giegengack and Grauch state that "almost nothing is known of the chronology of climatic change at latitudes of 8°45′ (north or south) anywhere in South America." Presumably, this relative lack of information also qualifies Giegengack and Grauch's arguments. A study of the glacial geology of the upper Santo Domingo River valley, which was in preparation at the time our report was being written (*1*) and which is now in print (*9*), has produced good evidence for correlating at least the last glacial retreat with that of the Sabana de Bogotá and other areas in the Cordillera Oriental of Colombia (*4, 7*). Radiocarbon dates (Table 1) performed on samples from two profiles of highly carbonaceous sediments within the Victoria morainal loop (probably representing glacial lagoon deposits), *overlying* fluvioglacial deposits and *underlying* the present soil, indicate that the glaciers had retreated before about 9000 years ago and represent a minimum age of the moraine.

In the Cordillera Oriental of Colombia, the lowest Würm Glacial snowline reached an elevation of about 3200 to 3000 m (*4*, p. 306). Valley glaciers probably advanced to lower elevations, and morainal remains were found at approximately 2700 m. This is almost exactly the situation found in the northern flank of the Sierra de Santo Domingo. Above 3000 m, glacial features in the Sierra de Santo Domingo (as around the Sabana de Bogotá) are well developed and fresh. These data also support our conclusion that Late Glacial events in the Venezuelan Andes may be correlated with those in the Cordillera Oriental of Colombia.

Undoubtedly, the Quaternary tectonic history of the upper Santo Domingo River valley is more complex than that outlined in our report (*1*), Giegengack and Grauch's comment, and this reply. There is, however, good reason to conclude that right-lateral strike-slip movement along the Boconó fault was predominant at least in postglacial times and that it is probably related to the interaction between two major lithosphere plates (Caribbean and Americas plates). This conclusion, and that concerning the probable rate of movement, remained unchanged.

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References and Notes

1. C. Schubert and R. S. Sifontes, *Science* **170**, 66 (1970).
2. E. Rod, *Amer. Assoc. Petrol. Geol. Bull.* **40**, 457 (1956).
3. H. F. Garner, *Geol. Soc. Amer. Bull.* **70**, 1327 (1959).
4. Th. van der Hammen and E. González, *Leidse Geol. Meded.* **25**, 261 (1960).
5. J. A. Nieto and J. M. Arroyo, Trabajo especial de grado, Facultad de Ciencias Forestales, Universidad de los Andes, Escuela de Ingenieria Forestal, Mérida, Venezuela (1968).
6. H. Walter and E. Medina, *Bol. Soc. Venez. Cienc. Nat.* **28**, 201 (1969).
7. Th. van der Hammen and E. González, *Geol. Mijnbouw* **39**, 737 (1960); *Leidse Geol. Meded.* **32**, 193 (1965); E. González, Th. van der Hammen, R. F. Flint, *ibid.*, p. 157.
8. R. F. Flint, *Glacial and Quaternary Geology* (Wiley, New York, 1971), pp. 432–434.
9. C. Schubert, *Bol. Inform. Asoc. Venez. Geol. Miner. Petrol.* **13**, 233 (1970); *Quaternaria*, in press.
10. M. A. Tamers, *Radiocarbon*, in press.
11. We thank E. Medina and J. E. Vaz for helpful advice and for reading the manuscript, and E. Castellanos for providing important climatic data.

11 June 1971

Endothelial Projections in Schlemm's Canal

Smith, Ryan, Michie, and Smith (*1*) reported finding endothelial projections on the endothelium of dog pulmonary artery. They comment, "the size and density of the projections suggest that they may function to direct an eddying flow of plasma along the endothelial surface."

In an ongoing study of more than 50 human eyes, I have noted such projections on the endothelium lining Schlemm's canal. Aqueous humor leaves the eye via the trabecular meshwork and canal of Schlemm to drain into the blood stream. As noted by Smith *et al.* (*1*) the endothelial projections are 0.2 to 0.8 μm in average size with a range from 0.1 to 0.5 by 0.5 to 3.0 μm. Figure 1 is a composite scanning and transmission electron microscopic view of these projections. These projections are of general interest in that there is little, if any, flow along the length of Schlemm's canal, and the protein content of human aqueous humor is 50 mg/100 ml (*2*) compared

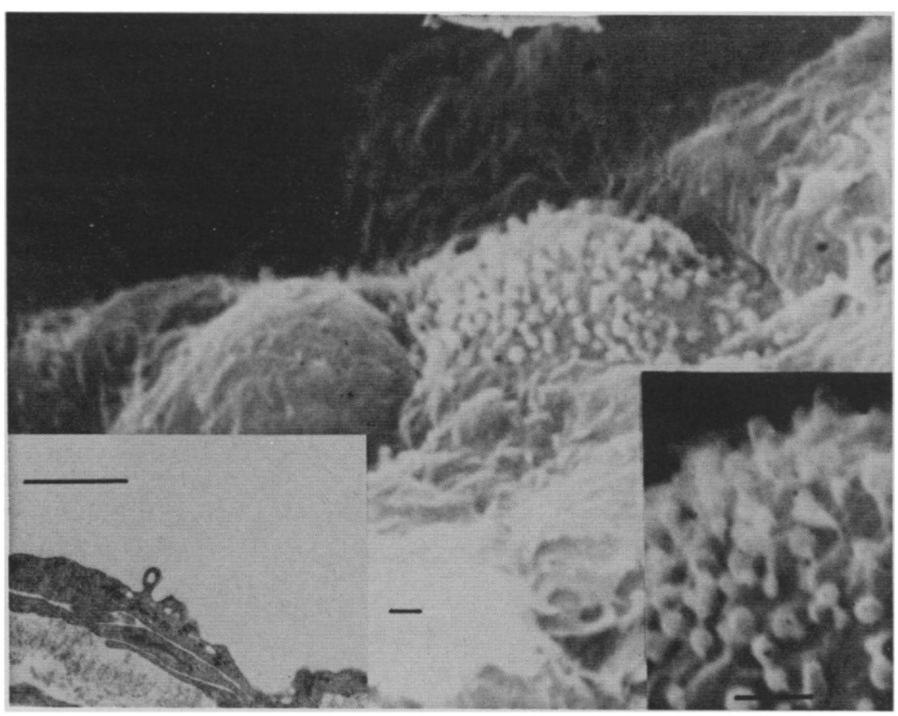

Fig. 1. Schlemm's canal from a 74-year-old man with normal eyes. The tissue was fixed in formalin and osmium tetroxide, prepared in a Pearce tissue drier, and examined in a Cambridge stereoscan microscope. The marker indicates 1 μm. The background view is looking into the canal, which was cut along its longitudinal axis. The trabecular meshwork is below. The projections are about 0.2 by 0.8 μm in size. They are more numerous on the endothelial cell in the center than on the others in the field. Also seen are 0.2 μm openings in the endothelial cells to the right and in the background. In the upper portion, some of the projections are caught in relief demonstrating their bulbous shape. The insert on the lower right is a higher magnification view of the central cell. To the left is a transmission electron microscopic view of a projection showing a micropinocytotic vesicle within it.