Evaluation of Chloride/Bicarbonate Exchange in the Human Colon in Vivo

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ABSTRACT During perfusion of a plasma-like solution, colonic absorption rate of chloride was much higher than the secretion rate of bicarbonate (34 vs. 3.5 meq/h, respectively). This might suggest that anion exchange (Cl/HCO_3) accounts for only a small fraction of total chloride absorption. However, if the colon absorbs as well as secretes bicarbonate, this reasoning would underestimate the magnitude of the anion exchange. To see if the colon absorbs bicarbonate, we perfused a chloride-free solution (which would eliminate bicarbonate secretion via Cl/HCO_3 exchange) and found that the colon absorbed bicarbonate at a rate of 5.1 meq/h. Calculation of electrochemical gradients and measurement of luminal fluid P_{CO_2} indicated that this bicarbonate absorption was mediated passively in response to electrical gradients, rather than via reversed Cl/HCO_3 exchange or acid secretion. The combined results of the plasma-like and chloride-free perfusion experiments suggest Cl/HCO_3 exchange at a rate of 8.6 meq/h (the sum of bicarbonate movements, 3.5 and 5.1 meq/h, observed in the two experiments). To obtain a second estimate under different experimental conditions, a choline chloride-choline bicarbonate (sodium-free) solution was perfused; with this solution, chloride and bicarbonate absorption dependent on active sodium transport should be eliminated or markedly reduced, and the magnitude of Cl/HCO_3 exchange should be revealed. This experiment suggested a Cl/HCO_3 exchange rate of 9.3 meq/h, similar to the first estimate. As chloride was absorbed at a rate of 34 meq/h during perfusion of the plasma-like solution, the Cl/HCO_3 exchange provides for approximately one-fourth of total chloride absorption.

INTRODUCTION

Previous work has shown that the human colon actively absorbs sodium (1–4), and that this in turn is responsible for a lumen-negative potential difference (PD)[1] across the mucosa (2–6). The colon also absorbs chloride and secretes bicarbonate, and it is generally believed that these anion movements are, at least in part, mediated by a Cl/HCO_3 exchange carrier of some sort (1–3, 7, 8). The magnitude of this exchange has not been determined, and that is the subject of this report.

As a first step towards estimating the magnitude of Cl/HCO_3 exchange, it is interesting to consider colonic absorption of physiological test solutions. When such solutions are perfused through the colon of normal subjects, chloride absorption greatly exceeds bicarbonate secretion (9). This might suggest that Cl/HCO_3 exchange accounts for only a negligible fraction of total chloride absorption. However, this reasoning neglects the possibility that bicarbonate might be secreted and absorbed simultaneously. If bicarbonate were absorbed as well as secreted by the colon, then up to 100% of colonic chloride absorption might be mediated by Cl/HCO_3 exchange, even though the rate of chloride absorption greatly exceeded the apparent rate of bicarbonate secretion.

The purpose of the present series of experiments was to evaluate the degree to which Cl/HCO_3 exchange accounts for chloride absorption by the human colon in vivo. First, we perfused the colon with a plasma-like solution, to compare chloride and bicarbonate movements under conditions where bicarbonate can be both absorbed and secreted. Second, we perfused a chloride-free test solution that contained bicarbonate. With this solution, bicarbonate secretion via Cl/HCO_3 should be eliminated (because there is no luminal chloride to exchange with plasma bicarbonate), and any bicarbonate absorption by the colon would be revealed. The sum of the bicarbonate secretion rate during perfusion of a plasma-like solution (the first experiment) and the bicarbonate absorption rate dur-

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[1] *Abbreviations used in this paper*: PD, potential difference; PEG, polyethylene glycol.

ing perfusion of the chloride-free solution (the second experiment) was used to estimate indirectly the magnitude of Cl/HCO_3 exchange. In a third experiment, we perfused a choline chloride-choline bicarbonate solution, whose bicarbonate and chloride concentrations were the same as in plasma. With this solution, chloride and bicarbonate absorption mediated by active sodium absorption should be reduced or eliminated, and the magnitude of Cl/HCO_3 exchange should be more directly evident. Finally, additional studies, involving measurements of luminal P_{CO_2} with and without acid and bicarbonate infusions, were carried out to evaluate the extent to which colonic absorption of bicarbonate (demonstrated in the second experiment) was mediated by H^+ secretion.

TABLE I
*Composition of Test Solutions**

	A Plasmalike	B Chloride-free	C Choline chloride-choline bicarbonate
Na	140	140	—
Choline	—	—	120
K	4	4	4
Cl	104	0	104
HCO_3	20	35	20
SO_4	10	54.5	—

* Concentrations are in millimoles per liter. All solutions contained 2 g/liter of PEG as a nonabsorbable marker; where necessary, additional PEG or mannitol was added to make the solutions isotonic to plasma.

METHODS

Perfusion studies. Steady-state colon perfusion studies were carried out in normal subjects when the distal port of a double-lumen tube was located in the cecum, and the proximal port was located 30 cm proximally in the terminal ileum. On the night before the study, the subject ingested a nonabsorbable salt solution (10) in quantities sufficient to induce watery diarrhea and, therefore, clean the colon; intestinal lavage with this solution results in neither absorption nor secretion of NaCl or water by the gastrointestinal tract. After an overnight fast, the position of the tube was confirmed by fluoroscopy. If necessary, small amounts of dilute barium were injected into the distal lumen to define the exact location.

Test solutions were infused through the proximal lumen at a rate of 20 ml/min. After a clear watery diarrhea ensued, 50 mg sulfobromophthalein was injected via the proximal port. When sulfobromophthalein was no longer detectable in the rectal effluent by alkalinization with NaOH, collections were started. By infusing in the distal ileum and collecting samples in the cecum (at a rate of 1.5 ml/min) and in the rectum (by means of a 16-Fr rectal tube), the entire colon was the test segment. In some studies, the aspirated cecal fluid was collected in airtight syringes, which were immediately sealed, and the rectal effluent was collected under oil so that pH and P_{CO_2} could be accurately assessed.

The electrolyte composition of the perfused test solutions is given in Table I. All solutions contained polyethylene glycol (PEG) as a nonabsorbable marker, 2 g/liter; where necessary, additional PEG or mannitol was added to make the solution isotonic to plasma.

PD measurements. PD was measured between a perfused test solution, which served as a flowing intraluminal electrode, and a subcutaneous reference electrode. This method has recently been described in detail (11). The electrodes were connected via 3 M KCl agar bridges and calomel half-cells to the input terminals of a battery-operated electrometer (Keithley Instruments, Inc., Cleveland, OH), and the output was displayed on a chart recorder (Rikadenki, Tokyo). The test solutions were perfused at a rate of 10 ml/min. PD was measured in the proximal colon by infusing test solution in the distal port of a double-lumen tube after completion of absorption studies. Distal colon PD was measured after completion of the proximal colon studies. 750 cm^3 of the test solution was infused into the lower colon via a rectal tube over a 15-min period, and then continuous infusion of the test solution was instituted at a rate of 10 ml/min via a smaller catheter attached to the rectal tube. This latter infusion served as the flowing intraluminal electrode.

Search for colonic hydrogen secretion. During the course of these experiments it became clear that the colon can absorb bicarbonate. One possible explanation for this absorptive process is colonic secretion of H^+ (12). To evaluate this, we measured luminal P_{CO_2} during perfusion of test solutions which did and did not contain bicarbonate. The assumption is that if bicarbonate absorption is mediated by H^+ secretion, then luminal P_{CO_2} will rise as bicarbonate-containing solutions are perfused. The principles of this method have been previously published (13).

To evaluate the significance of a rise in colonic fluid P_{CO_2} in terms of the rate of H^+ secretion, we infused known amounts of acid into the colon. A triple-lumen tube was constructed, with two sides opening into the proximal end of a larger 3-cm long polyvinyl tube (i.d. of 2 mm and o.d. of 3.5 mm), which functioned as a mixing chamber. Acid was infused into a mixing chamber, rather than into the colon per se, to avoid the possible hazards of direct contact of colon mucosa and acidic solution. The distal end of the mixing chamber was open, so that fluid infused into its proximal end could exit via the distal opening. The third lumen of the triple-lumen tube opened 10 cm beyond the distal opening of the mixing chamber. Studies were begun when the mixing chamber was located in the cecum or ascending colon.

Two solutions were infused simultaneously into the mixing chamber. The first was a low chloride (bicarbonate-containing) solution (similar to solution B, Table I), which was infused at a rate of 15 ml/min. The second solution contained sulfuric acid and was infused at a rate of 5 ml/min. The concentration of acid was 0, 5, 10, or 40 meq/liter, which resulted in acid infusion rates of 0, 1.5, 3, or 12 meq/h. The exact makeup of the acid solutions is given in the footnote of Table IV. Each acid solution was perfused for 90 min; fluid collected from the distal port of the triple-lumen tube and from a rectal tube was discarded during the first 60 min of each acid infusion period (equilibration time), and then collected anaerobically for the next 30 min and analyzed immediately for P_{CO_2}.

Analysis of samples and calculation of results. Infused test solutions, aspirated samples, and rectal effluent were analyzed for PEG by the Hyden method (14), and electro-

lytes were determined by standard techniques (11). Net water and electrolyte movement was calculated by standard nonabsorbable marker equations (15), with PEG as the nonabsorbable marker. The pH and P_{CO_2} were determined with a blood gas analyzer.

Ethical consideration. This research project was approved by a Human Research Review Committee on January 14, 1981, and informed written consent was obtained from each participant.

RESULTS

Perfusion of plasmalike solution. Table II shows net water and electrolyte movement during perfusion of the plasmalike solution (solution A, Table I) in six subjects. Bicarbonate was secreted at a rate of 3.5 meq/h. The PD was −21 mV (lumen-side negative) in the proximal colon and −51 mV in the distal colon, and the concentration of bicarbonate rose from ~20 to ~27 meq/liter as fluid traversed the colon. Considering that the plasma bicarbonate concentration in these subjects was 24 meq/liter, bicarbonate was secreted against an electrochemical gradient.

Water, sodium, and chloride were absorbed when this solution was perfused. The rate of bicarbonate secretion was quite small compared with the chloride absorption rate. Net potassium movement was nil. Measured net cation (Na + K) and measured net anion (Cl + HCO_3) movement rates were similar.

Perfusion of chloride-free solution. Perfusion of this solution resulted in luminal colonic fluid that contained a chloride concentration of only 6 meq/liter, and colonic chloride absorption in this experiment was nil. Therefore, bicarbonate secretion via Cl/HCO_3 exchange should be negligible or at least markedly reduced compared with secretion when the colon was perfused with a plasmalike solution. Thus, this experiment should show the extent to which the colon can absorb bicarbonate.

As shown in Table II, perfusion of the chloride-free solution was associated with a bicarbonate absorption rate of 5.1 meq/h. Water and sodium absorption were reduced, compared with absorption when a plasmalike solution was perfused. Potassium movement was near zero, as it was with the plasmalike solution.

TABLE II
Water and Electrolyte Movements, Luminal Electrolyte Concentrations, and PD during Colonic Perfusion of Three Test Solutions

Solution*	Plasmalike	Chloride-free	Choline chloride-choline bicarbonate
	$n = 6$	$n = 7$	$n = 6$
Net H_2O‡	−203±20	−47±15	−13±8
Prox§ [Na]	143.3±0.4	140.2±0.4	12.8±1.6
Dist‖ [Na]	142.0±0.6	139.9±0.4	10.8±1.4
Net Na movement¶	−30.5±3.2	−7.0±2.0	−2.9±0.8
Prox [K]	4.4±0.1	5.0±0.2	3.7±0.2
Dist [K]	5.2±0.2	5.6±0.1	3.8±0.2
Net K movement¶	−0.0±0.2	+0.5±0.1	0.0±0.1
Prox [Cl]	104.8±1.3	6.2±1.1	101.3±1.3
Dist [Cl]	95.1±1.8	6.2±0.9	92.8±1.7
Net Cl movement¶	−34.3±4.1	−0.2±0.7	−13.2±1.6
Prox [HCO_3]	19.6±1.1	34.2±1.5	27.0±0.8
Prox [HCO_3]	27.2±1.9	30.7±1.3	34.2±1.2
Net HCO_3 Movement¶	+3.5±1.2	−5.1±1.1	+9.3±1.6
PD**			
Proximal Colon	−21±2	−38±4	+5±5
Distal Colon	−51±7	−65±8	−21±8

Prox, proximal; Dist, distal.
* See table I for composition.
‡ (−) absorption in milliliter per hour.
§ Concentration at proximal collecting site in milliequivalents per liter.
‖ Concentration at distal collecting site (rectum) in milliequivalents per liter.
¶ (−) absorption, (+) secretion in milliequivalents per hour.
** (−) lumen-negative PD; (+) lumen-positive PD.

Perfusion of choline chloride-choline bicarbonate solution. Perfusion of this solution resulted in colonic fluid that contained chloride and bicarbonate in concentrations similar to those found in plasma. The test solution itself was free of sodium, but the fluid that arrived at the cecal sampling site contained 12.8 meq/liter of sodium, derived from endogenous small bowel contents and by passive diffusion across ileal mucosa. Although there was, therefore, some sodium present in the colonic lumen, its concentration was very low compared with that with the plasmalike solution, and events dependent on active sodium absorption should be markedly inhibited by perfusion of this test solution. In agreement with this prediction, the PD across the proximal colon was +5 (not significantly different from zero) compared with −21 mV with the plasmalike solution, and PD across the distal colon was −21 mV compared to −51 mV with the plasmalike solution. Under these conditions, passive bicarbonate absorption in response to electrical gradients would be greatly reduced as would chloride absorption mediated in some way by sodium absorption. Thus, the degree to which chloride is absorbed and bicarbonate is secreted by Cl/HCO_3 exchange would be more apparent with this than with other test solutions.

The results, given in Table II, show that chloride was absorbed at a rate of 13.2 meq/h, whereas bicarbonate was secreted at a rate of 9.3 meq/h. Sodium was absorbed in an amount about equal to the difference in the rates of these anion movements.

Search for hydrogen secretion. Perfusion of the chloride-free solution (data presented above) revealed that colonic mucosa can absorb as well as secrete bicarbonate. There are several ways in which the colon might absorb bicarbonate, including secretion of H^+. H^+ secretion is known to occur in both the human jejunum and ileum (13, 16).

To search for H^+ secretion, we measured P_{CO_2} of fluid collected from the proximal and distal ends of the colon during perfusion of bicarbonate-free and bicarbonate-containing test solutions. Perfusion of the bicarbonate-free solution should establish the base-line value of colonic fluid P_{CO_2}, in the absence of bicarbonate absorption. If the colon absorbs bicarbonate by secreting H^+, then colonic fluid would be expected to develop a high P_{CO_2} when bicarbonate-containing test solutions are perfused.

As shown in Table III, during perfusion of a bicarbonate-free test solution into the terminal ileum, cecal, and rectal fluid had a P_{CO_2} of 46–47 mmHg. On the other hand, when the terminal ileum was perfused with a bicarbonate-containing solution, cecal, and rectal fluid had a P_{CO_2} of 54 mmHg. The difference in P_{CO_2} in cecal fluid, with and without bicarbonate, could reflect H^+ secretion by the terminal ileum as well as or rather than by the proximal colon. On the other hand, the P_{CO_2} of rectal fluid during bicarbonate perfusion was 7 mmHg higher than when a bicarbonate-free solution was perfused. It seems unlikely that ileal hydrogen secretion could influence the P_{CO_2} of fluid collected in the rectum, so these results suggest the possibility of colonic H^+ secretion. The difference in rectal fluid P_{CO_2} with and without bicarbonate was not statistically significant, however, ($P = 0.1$); therefore, these results can only be considered suggestive.

As just noted, if we assume (despite the lack of statistical significance) that rectal P_{CO_2} is 7 mmHg higher when bicarbonate is perfused than when it is not, this would indicate that the colon secretes H^+. However, the magnitude of H^+ secretion required to produce such a change in P_{CO_2} would not be evident from these results. We, therefore, performed an additional study wherein known amounts of acid were infused into the colon, while a bicarbonate-containing test solution was

TABLE III
pH and P_{CO_2} in the Colon during Perfusion of Bicarbonate-free and Bicarbonate-containing Solutions

	Infusion		Proximal		Distal	
	P_{CO_2}	$[HCO_3]$	P_{CO_2}	$[HCO_3]$	P_{CO_2}	$[HCO_3]$
	mmHg	*meq/liter*	*mmHg*	*meq/liter*	*mmHg*	*meq/liter*
HCO_3-free (n = 11)	54±2	0	46±1	3.6±1.0	47±3	6.7±2.0
HCO_3-containing (n = 18)	51±1	36.8±0.7	54±1	36.4±1.2	54±2	39.2±2.2
P Value			<0.001		0.1	

* HCO_3-free solution was similar to solution A in Table I but without bicarbonate, and was made isotonic by the addition of sulfate. HCO_3-containing solution was similar to solution A in Table I.

perfused simultaneously (see Methods). As shown in Table IV and Fig. 1, hydrogen infusion rates of 1.5, 3, and 12 meq/h caused a rise in P_{CO_2} of fluid collected from the proximal colon, and although P_{CO_2} fell as fluid traversed the colon, the P_{CO_2} of rectal effluent was still higher at all acid infusion rates than when acid was not infused. By extrapolation, with the data in Fig. 1, it would require acid secretion of only 1.0 meq/h to give a 7-mmHg rise in rectal fluid P_{CO_2}. Thus, we conclude that H^+ secretion could contribute only a small amount, if any, to the overall rate of bicarbonate absorption (5.1 meq/h) noted during perfusion of a chloride-free solution.

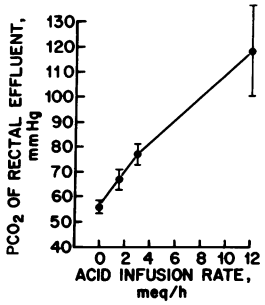

FIGURE 1 The effect of different cecal acid infusion rates on P_{CO_2} of fluid collected in the rectum. Five normal subjects were studied.

DISCUSSION

During perfusion of a plasmalike solution, we measured a colonic chloride absorption rate of 34 meq/h and a bicarbonate secretion rate of only 3.5 meq/h. However, one cannot conclude from this experiment that Cl/HCO_3 exchange accounts for only 3.5 meq/h of the chloride that is absorbed. This is because the observed rate of bicarbonate secretion might underestimate the true rate of bicarbonate secretion, if the colon absorbs as well as secretes bicarbonate.

To determine if the colon absorbs bicarbonate, we perfused a chloride-free solution; this eliminated chloride absorption, and presumably eliminated or markedly reduced bicarbonate secretion by Cl/HCO_3 exchange. During perfusion of this chloride-free solution, bicarbonate was absorbed at a rate of 5.1 meq/h. Further studies, using P_{CO_2} as a marker of intraluminal reaction of HCO_3^- and H^+, suggested that this bicarbonate absorption was mediated to only a small extent, if at all, by colonic H^+ secretion. Therefore, it seems reasonable to conclude that the colon absorbs bicarbonate ions per se. Theoretically, this might be mediated by reversed Cl/HCO_3 exchange; as chloride was not secreted in this experiment, this mechanism would require simultaneous passive chloride reabsorption. However, the existing electrochemical gradients across the mucosa (see Table II) would not support passive chloride absorption (according to the Nernst equation). Thus, bicarbonate absorption via reversed Cl/HCO_3 exchange is unlikely. Although the mechanism of bicarbonate absorption during perfusion of a chloride-free solution is not certain, the most likely explanation is passive bicarbonate ion absorption secondary to the electrical gradient generated by active sodium absorption.

By adding the absorption rate of bicarbonate during perfusion of the chloride-free solution (5.1 meq/h) to the observed rate of bicarbonate secretion during perfusion of the plasmalike solution (3.5 meq/h), we estimate the true rate of bicarbonate secretion during perfusion of the plasmalike solution to be 8.6 meq/h. This analysis suggests that Cl/HCO_3 exchange during perfusion of the plasmalike solution is about one-fourth as large as the total chloride absorption rate.

To further assess the magnitude of Cl/HCO_3 exchange, it was desirable to perfuse the colon with a solution that would allow Cl/HCO_3 exchange to proceed unabated, while at the same time removing or reducing the factors that simultaneously cause bicarbonate to be absorbed. As our results suggest that bicarbonate ion absorption could be dependent on active sodium absorption, it seemed possible that this objective might be accomplished by perfusing the colon with a sodium-free, choline chloride-choline bicarbonate solution. When we perfused this solution into the terminal ileum, fluid aspirated from the cecum contained only 12.8 meq/liter of sodium, and sodium absorption in the colon was markedly reduced (from 30.5 to 2.9 meq/h, compared with the plasmalike so-

TABLE IV
pH and P_{CO_2} in the Colon during Exogenous Acid Infusion (n = 5)

Acid* infusion rate	pH		P_{CO_2}	
	Proximal	Distal	Proximal	Distal
meq/h			*mmHg*	
0	7.53±0.03	7.46±0.01	53±2	56±2
1.5	7.41±0.01	7.38±0.03	72±2	67±4
3.0	7.32±0.03	7.34±0.02	99±13	77±4
12.0	6.93±0.05	7.14±0.10	175±29	118±19

* Infused solution to achieve these acid infusion rates consisted of solution B in Table I at 15 ml/min and one of following solutions (in milliequivalents per liter) at 5 ml/min. For 0 meq/h, Na_2SO_4 145, K_2SO_4 4; for 1.5 meq/h, Na_2SO_4 140, K_2SO_4 4, H_2SO_4 5; for 3.0 meq/h, Na_2SO_4 135, K_2SO_4 4, H_2SO_4 10; and for 12.0 meq/h, Na_2SO_4 105, K_2SO_4 4, H_2SO_4 40. All solutions were made isotonic with 60 g/liter of PEG.

lution). The lumen-negative PD across the colon was also markedly reduced. Under these conditions, chloride and bicarbonate were present in colonic fluid in concentrations equal to their concentrations in plasma. Unlike the situation with the other two perfused test solutions, these anions were therefore free to exchange across the mucosa under experimental conditions that should reduce the factors favoring simultaneous reabsorption of secreted bicarbonate ions. The persisting electrical gradients would be unlikely to influence anion movement across the Cl/HCO_3 exchange, because electrical forces would have the same influence on both anions.

When the choline chloride-choline bicarbonate solution was perfused, we found that bicarbonate was secreted at a rate of 9.3 meq/h, whereas chloride was absorbed at a rate of 13.2 meq/h. The difference was nearly matched by the sodium absorption rate of 2.9 meq/h. The most logical explanation for these findings is that the Cl/HCO_3 exchange operated at a rate of 9.3 meq/h, and that an additional 2.9 meq of chloride was absorbed with sodium. However, we cannot exclude the possibility that some of the secreted bicarbonate (rather than chloride) was reabsorbed with sodium, which could mean that the Cl/HCO_3 exchange operated at a rate somewhere between 9.3 and 13.2 meq/h. The lower value is in excellent agreement with our other estimate of 8.6 meq/h (which was based on addition of observed bicarbonate movements during perfusion of the plasmalike and the chloride-free test solutions). Therefore, all the data combined suggest that the human colon Cl/HCO_3 exchange operates at a rate of ~9 meq/h.

Although it has so far not been possible to accurately measure bicarbonate movement in in vitro preparations of intestine placed in Ussing chambers, it is nevertheless interesting to compare our results in vivo with those of Hawker et al. (3) in short-circuited colonic mucosa. These workers observed sodium and chloride absorption rates of 6.9 and 2.4 μeq/cm per h, respectively. Thus, the chloride absorption rate was 35% of the sodium absorption rate under in vitro conditions where electrical and chemical forces favoring passive ion movements were eliminated. In our study in vivo, the estimated rate of Cl/HCO_3 exchange (~9 meq/h) was equal to 30% of the measured rate of sodium absorption during perfusion of the plasmalike solution. Thus, if it is assumed that all active chloride absorption in vitro is mediated by Cl/HCO_3 exchange, the magnitude of this exchange, relative to the rate of active sodium absorption, is similar to what we have calculated for human colon in vivo.

Our data suggest that Cl/HCO_3 exchange can account for about one-fourth of the chloride that is absorbed by the human colon in vivo during perfusion of physiological solutions.[2] Thus, there is a large fraction of chloride absorption that is independent of anion exchange—~25 meq/h. This anion exchange independent fraction of chloride absorption was markedly reduced (to at least 2.9 meq/h) when active sodium absorption was reduced by perfusion of the colon with a sodium-depleted solution. These observations suggest that the anion exchange independent fraction of chloride absorption is related to active sodium absorption. This could most easily be explained by postulating passive chloride absorption in response to electrical gradients generated by active sodium pumping, although some form of NaCl cotransport might also be involved.

An unexpected observation made during the course of these experiments is that the colon did not secrete potassium, even when cation secretion was favored by large electrochemical gradients (Table II). This finding suggests that the normal human colon is virtually impermeable to potassium. Therefore, the very high concentration of potassium in normal stool water (17) probably reflects mainly a contraction phenomenon (the colon absorbs water and the potassium concentration is thereby elevated), rather than passive potassium secretion by the colon. Obviously, in disease states abnormal permeability or active potassium secretion might also play a role in elevating the potassium concentrations in stool water.

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[2] We have been unable to find data in the literature on dogs, rats, or rabbits that allows calculation of the magnitude of Cl/HCO_3 exchange; therefore, it is not known whether or not our estimate for the human colon is generally applicable to other species.

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