from 100% at the 1% level of confidence. It would appear that the inclusion of urea usually has a small stimulatory effect on acid secretion with elevated P_{O_2}, and occasionally has a marked effect. Since urea is a normal constituent of elasmobranch plasma, its inclusion would appear justified even in the absence of entirely satisfactory statistics as to its effect, and it is included in the experiments to follow.

The apparatus used for the hyperbaric experiments did not previously allow pressures above 2 atm; thus, it was not known whether a P_{O_2} of 1.9 atm was sufficient to remove O_2-limitation, or whether high levels of O_2 might be toxic. With a modified apparatus, a series of tissues mounted in urea-containing solutions was tested at P_{O_2} of 0.9 and 2.9 atm (at constant P_{CO_2} = 0.1 atm) with the results shown in Table 2. Each condition was maintained for 1.5 hours, and the order of the conditions was random. The difference in acid secretory rate between 0.9 and 1.9 atm is significant, as expected from previous work, while the small difference between 1.9 and 2.9 atm is not significant ($0.3 < P < 0.4$), and does not become so when a paired comparison is used. On this basis I conclude that the relief of O_2-limitation of acid secretion is complete at P_{O_2} of 1.9 atm or below, and that no toxic effects of O_2 exist at this level. Supported by NSF PCM 77-03336.

THE CURRENT-VOLTAGE PLOT IN DOGFISH GASTRIC MUCOSA

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Transepithelial resistance is conventionally measured by passing a brief current pulse across the tissue, recording the resulting voltage transient. For proper choice of pulse length, the resistance is unchanged by minor variations in length, and seems to represent a composite of membrane resistances and pericellular shunt contributions. If none of these resistances were functions of current or voltage, a plot of voltage vs. current would be a straight line passing through the open circuit potential and having a slope ($\Delta V/\Delta I$) equal to the tissue resistance. In a number of tissues with high pericellular shunt resistances, such I-V plots are multilinear; i.e., they consist of several straight line (constant resistance) segments which intersect at well-defined breakpoints, with short transition regions connecting the straight segments. Such is the case for the frog gastric mucosa (unpublished observations). I shall now report similar observations on the stomach of the dogfish, *Squalus acanthias*.

The gastric mucosa, stripped of its heavy muscle layers, was mounted as a flat sheet (3.14 cm^2 area) in a plexiglass chamber. Mucosal and serosal solutions were those of Hogben (Science 129:1224, 1959) with the addition of 350 mM urea to each (see previous paper). Voltage was recorded via KCl/calomel fiber junction "reference electrodes" inserted into the fluid streams, and displayed on a strip chart recorder (Bio-Rad 1310) with 99% response time of 0.35 seconds for half-scale deflection. Current was supplied by a constant current generator (ELS CS-1, courtesy of Dr. S. I. Helman) via Ag/Ag Cl electrodes remote from the tissue. Current pulses of 0.8 second duration were sent every 30 seconds, reversing the polarity between pulses, and increasing the current intensity stepwise after each pair of pulses. With slow chart speeds used, the voltage response appears as a "spike," and the recorded value is the maximum obtained within the limits of the recorder response time. Reported resistances are corrected for a chamber resistance of 10 ohms (31.4 ohm·cm^2).

Like the frog gastric mucosa, that of the dogfish shows a multilinear I-V relationship of which Figure 1 is a striking example. The observed points clearly do not fall on a single straight line, nor on any reasonable higher-order curve, but are resolved into 3 straight line segments, with breakpoints at -22 mV (reference mucosal solution = 0) and +50 mV. There is a large difference in resistance across the mucosal-positive breakpoint and a smaller difference across the serosal-positive breakpoint;

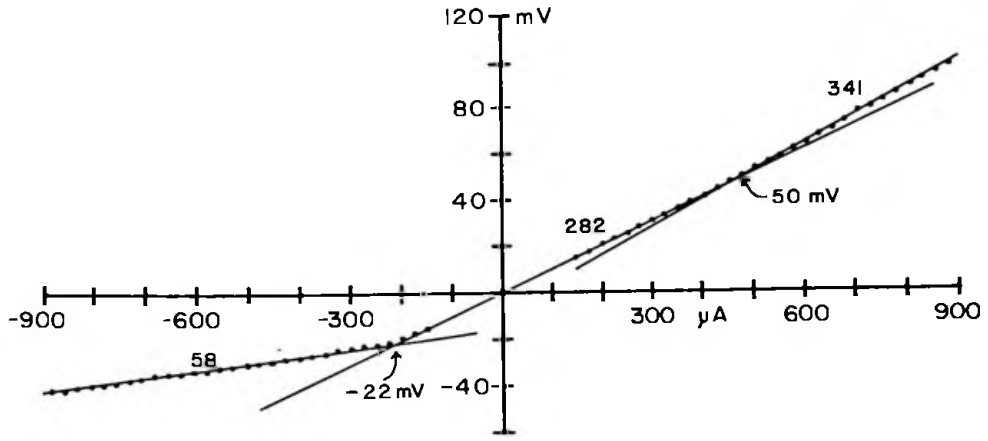

Figure 1. Plot of voltage vs. current for dogfish gastric mucosa, determined as specified in the text. Currents are per 3.14 cm^2 chamber; voltage is maximum recorded. Numbers above line represent slope in ohm·cm^2, corrected for chamber resistance of 10 ohms. Gap in center of record due to technical limitations of current source.

indeed, in many tissues the latter breakpoint cannot be observed, although the former is usually seen (1 failure in 15 experiments).

I-V plots were constructed for a series of tissues being used for other investigations. Such a series is summarized as Table 1, in which the value of the mucosal-positive breakpoint and the resistances around it are shown in two conditions of oxygenation. Despite the large change in secretory

TABLE I

Third-Quadrant Breakpoint Voltages and Resistances

	CONDITION								RATIOS		
	P_{O_2} = 0.9 atm				P_{O_2} = 1.9 atm						
Date	BP*	R_1	R_2	R_1/R_2	BP	R_1	R_2	R_1/R_2	R_1 0.9 / R_1 1.9	R_2 0.9 / R_2 1.9	BP 0.9 / BP 1.9
8/15/78	-26.5	222	146	1.51	-17.5	132	97	1.35	1.68	1.50	1.51
	-25.0	240	160	1.50	-12.5	138	115	1.20	1.74	1.4	2.00
8/17/78	-28.0	380	181	2.10	-31.5	277	131	2.01	1.37	1.32	0.89
	-23.0	295	239	1.23	-24.0	283	149	1.89	1.04	1.60	0.95
8/28/78	-22.5	171	78	2.21	-19.0	163	61	2.65	1.06	1.26	1.18
8/29/78	-12.5	137	88	1.55	-25.0	199	133	1.49	0.68	0.65	0.50
8/31/78	-30.0	324	189	1.71	-29.0	330	97	3.38	0.98	1.93	1.03
Avg.	-23.9	253	154	1.69**	-22.6	217	113	2.00**	1.07	1.38**	1.15
SEM	± 2.2	±32	±21	±.13	± 2.5	±30	±11	±.30	±.20	±.15	±.18
Units	mV	ohm·cm^2	ohm·cm^2	-	mV	ohm·cm^2	ohm·cm^2	-	-	-	-

LEGEND FOR TABLE I

*BP = breakpoint voltage; intersection of straight lines. The other breakpoint at ∿ +50 mV is ignored if present. R_1 = resistance determined by slope of line at voltages more positive than breakpoint. R_2 = resistance at voltages more negative than breakpoint.

**Significantly different from 1.00 by t-test ($0.02 < P < 0.05$). R_1 and R_2 for each condition significantly different from each other; no other differences significant.

rate upon changing from 0.9 atm O_2 to 1.9 atm O_2 (1.45 to 6.71 µEq/cm^2·hr) there is no demonstrable change in breakpoint voltage or the resistance around zero current (R_1) when these averages are

subjected to Student's t-test. The resistance at mucosal-positive voltages greater than the breakpoint (R_2) is significantly ($0.02 < P < 0.05$) decreased by the increase in P_{O_2}, as determined from the ratio of the resistance (1.38 ± 0.15) in the two conditions. Variability between tissues makes the comparison of resistances not significant when unpaired values are used. It would appear that any information regarding acid secretion is contained in the R_2 resistance region.

In frog skin, it has been suggested (Helman, O'Neil and Fisher, Am. J. Physiol. 229:947, 1975) that the breakpoint around +140 mV, which agrees with the calculated emf of a Na^+ electrogenic pump, is a measure of this pump potential. The dogfish gastric mucosa secretes H^+ from a serosal (and presumably cellular) pH of around 7.4 into a region with a calculated pH 0.5 or so. For this process, the pump emf should be about -380 mV, which is far beyond the range explored in these experiments. However, if the primary secretion is HCl at this pH, the required pump emf for Cl^- is +80 mV, which is in rough agreement with the values observed in those cases where a serosal-positive breakpoint can be found. Caution is indicated, however, by the experience with the frog gastric mucosa, in which a large number of breakpoints are found at voltages from +200 to -150 mV. It seems likely that more breakpoints will be found when the dogfish tissue is explored over a wider range.

It is recognized that the present experiments should be repeated under better conditions. The method of altering the secretory rate could be improved, higher currents are required, and the recording of voltage pulses used in this study ignores time-dependent factor which may be of importance. It is clear, however, that this tissue does show a multilinear I-V relationship, which must be explained as a part of any complete understanding of the electrophysiology of the tissue. Supported by NSF PCM 77-03336.

FURTHER STUDIES OF ADAPTATION TO FRESHWATER BY *Anguilla rostrata*

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When American eels (*Anguilla rostrata*), fully adapted to seawater, are placed for brief periods of time in freshwater, the efflux of sodium and chloride is markedly depressed and remains low even after re-immersion in full-strength seawater. Outward transfer of salt is thus inhibited even though gill Na-K-ATPase remains at the high level characteristic of seawater adaptation (Bull. MDIBL, 15:31-32, 1975). Neither the afferent stimulus nor the effector mechanism responsible for this turn-off of gill secretion has been identified.

Anguilla rostrata weighing 40-100 g, trapped in fresh water, were adapted to seawater for at least 3 weeks before they were studied. The efflux of ^{36}Cl was measured by injecting 2 microcuries intraperitoneally in a volume of 0.2 ml, allowing equilibration for at least an hour, determining the quantity of isotope appearing in the aerated bathing medium (1 liter of seawater at 16°C) over the course of the subsequent hour, and dividing by the specific activity of ^{36}Cl in plasma.

The plasma clearance of ^{36}Cl in 8 eels fully adapted to seawater was 5.74 ± 3.30 ml/hr/100 g (mean ± s.d.) and in 8 freshwater eels, 0.8 ± 0.3. After one hour of exposure to freshwater, ^{36}Cl clearance remained high, averaging 3.70 ± 2.07 (n=8), but after 2 hours of freshwater exposure it fell to 0.61 ± .59 (n=12). Previous studies had demonstrated a similar sequence of events for sodium efflux (Bull. MDIBL, 15:31-32, 1975). It is natural to suppose that dilution of the blood in freshwater is the signal for the turn-off of sodium and chloride efflux, but plasma sodium concentration in 8 eels was not significantly lowered by 2 hours of freshwater exposure (157.3 ± 3.4 mEq/L before vs. 156.7 ± 3.3 after), while plasma chloride fell only slightly, from 146.8 ± 5.5 mEq/L to 142.1 ± 4.5. Nevertheless, preliminary injection of hypertonic saline (0.3 ml of 2.5 M NaCl per 100 g) successfully prevented the turn-off of chloride efflux normally produced by 2 hours of freshwater exposure. Such