pressure is elevated in old SHR (41 weeks old) with high systemic pressure (172 mm Hg) as compared to younger ones given in the table: the wall stress was increased to about 32% in A3 of the old animals (⌀ 17.7±0.2 µm, $\sigma = 2.98 \pm 0.14 \times 10^5$ dyn/cm^2).

Obviously, the elevated precapillary pressure and the increased tangential wall stress in hypertensive animals indicate an insufficiently increased flow resistance in series; in addition, the elevation of the flow resistance in spontaneous hypertension is also caused by an increased parallel resistance[20]. The findings of a decrease in the number of resistance vessels (rarification) in spontaneous hypertension[13,14] could furthermore favour our conclusion.

Intravitally measured tangential wall stress in arterioles of different branching order in normotensive (NR) and spontaneously hypertensive rats (SHR)

	A2	A3	A4
NR	1.66±0.43	0.94±0.05	0.76±0.27
SHR	3.80±0.78	2.26±0.21	1.69±0.21
Δ%	+129%	+140%	+122%

The data are given as mean values ± SEM (× 10^5 dyn/cm^2); the percent differences are added.

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Action of glutamic acid and of some glutamate analogues on the molluscan central neurones

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Sumary. The effects of L-glutamic acid and of some glutamate analogues have been studied on the central nervous system of the snail *Heobania vermiculata*, using conventional electrophysiological techniques. The glutamate H-response had the mean equilibrium value of −(57±4) mV and was associated with a Cl^- conductance change. The D-response to glutamate application showed an involvement of sodium ions. Aspartate was agonist of glutamate action and displayed similar equilibrium value of the H-response, whereas quisqualate H-response was 'non-invertible'.

L-glutamic acid is probably an excitatory transmitter in the mammalian central nervous system[2], and in crustaceans[3] and insects[4] it is suggested as chemical transmitter at many excitatory neuromuscular junctions. In molluscs, L-glutamic acid was found to evoke depolarizing and hyperpolarizing potentials in the nerve cells[5-7]. The present report is a study of some characteristics of glutamate receptors on ganglion cells in the land snail *Heobania vermiculata* (Helicidae).

Methods. The experiments were carried out in the left parietal, visceral and right parietal ganglia. The techniques have been described previously[8]. Intracellular records were obtained from giant nerve cells of ganglion dorsal surface with microelectrodes filled with K^+-acetate 1.5 M; Snail-Ringer: NaCl, 75 mM; KCl, 5 mM; MgCl, 15 mM; $CaCl_2$, 10 mM; Tris/HCl, 5 mM; pH, 7.8.

Glutamate and its analogues (D-glutamate, L-aspartate, L-α-Kainate, DL-homocysteate, N-methyl-DL-aspartate, L-quisqualate), were applied locally to a given cell by iontophoresis from a single micropipette filled with a concentrated solution of Na-glutamate or Na-glutamate analogue (0.2 M, pH 7.3).

Results and discussion. A depolarizing or hyperpolarizing potential was observed when glutamate ions were applied iontophoretically to the soma membrane of some nerve cells. A weaker response to glutamate was observed if the glutamate pulse was repeated a few sec later, presumably because of receptor desensitization. The latency, onset and time course of the glutamate response potential were variable, even when the glutamate was applied to different regions of the same cell. This variability may be due to the interposition of non-neural elements between the probe and the active membrane, or to non-uniform sensitivity to glutamate over the cell body surface. In addition it was not rare to observe a biphasic response to glutamate application.

The mean value of the equilibrium potential (±SD) for the H-response (hyperpolarizing potential), determined by introducing a 2nd electrode in 5 different somata, was (57±4) mV. The H-response to glutamate had reversed 6–8 min after Cl^--free saline (Cl^- substituted by the impermeant sulphate anion) entered the bath.

Over a period of 40–60 min, the new 'depolarizing' H-response declined in amplitude and disappeared completely. Reapplication of normal saline to preparation caused the reappearance of the H-response. No significative varia-

tion of equilibrium level for H-response was observed when external potassium, sodium or calcium was removed (Na^+ and K^+ substituted by $Tris^+$; Ca^{2+} substituted by Mg^{2+}). These experiments, summarized in figure 1, indicate a chloride involvement in the H-response.

The D-response (depolarizing response) to glutamate was unchanged in Cl^--free medium and was abolished in Na^+-free medium over a period of 20–30 min, indicating presumably a sodium involvement in the D-response. It was not possible to observe an inversion of the D-response because of the rectification which developed above −35 mV.

Other experiments are carried out to characterize the receptors involved in H and D-response to glutamate, by testing the effect of iontophoretic application of the glutamate analogues. Only L-aspartate and L-quisqualate were able to affect the soma of some cells. In most of the somata sensitive to glutamate (total number 27 of the 56 neurones tested in 18 different preparations), quisqualate was able to act as agonist of the glutamate excitatory action, but rarely as agonist of the glutamate inhibitory action. On the contrary, L-aspartate was agonist of glutamate action. Figure 2 shows 2 examples of the action of glutamate and of quisqualate in the same somata. The equilibrium values for the H-response to glutamate and to aspartate were very similar whereas the hyperpolarization induced by quisqualate could not be inverted (3 experiments). Other 'non-invertible' hyperpolarizations have been previously described[9,10].

From these data it may be concluded that: a) Glutamate may be acting on 2 types of receptors since it was found to evoke depolarizing and hyperpolarizing potentials in the somata, with different ionic mechanisms. b) The structural requirement for glutamate receptors in *Heobania* brain shows differences with those proposed in other specimens of molluscs[6,11,12].

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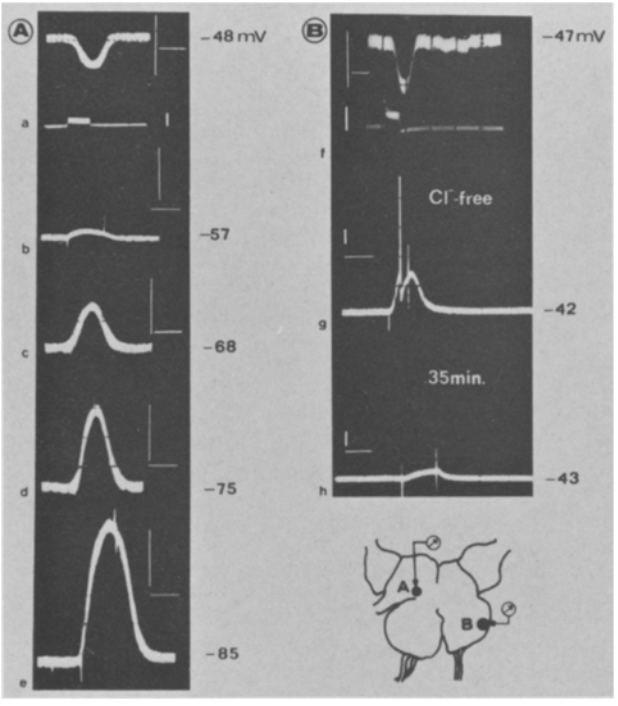

Fig. 1. Chloride involvement in the H-response to glutamate.
Left column: reversal potential measurement in the neurone A. *a* Upper trace, intracellular recording; lower trace, glutamate ions current monitor. Equilibrium potential value, −56 mV.
Right column: intracellular recording during Cl^--free saline perfusion, from cell B. *f* Upper trace, intracellular recording; lower trace, glutamate ions current monitor. *g* 'depolarizing' H-response in Cl^--free saline. *h* 35 min after start of Cl^--free saline perfusion. Vertical bars, 10 mV; 150 nA. Horizontal bars, 3 sec. Isolated preparation. Temperature 22 °C.

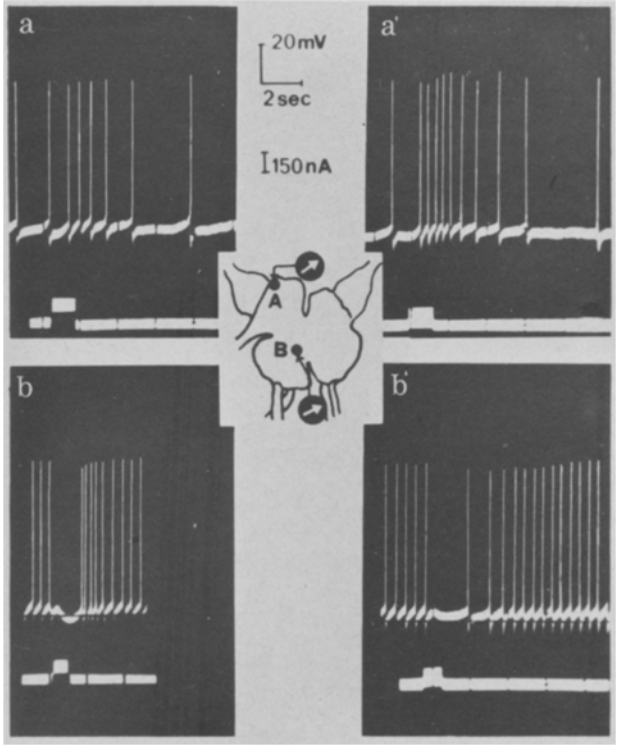

Fig. 2. Responses to glutamate and to quisqualate in different cells of the same isolated preparation. In these cells quisqualate and aspartate were able to act as agonists of both excitatory and inhibitory actions of glutamate. Upper traces, intracellular recordings; lower traces, current monitor.
a D-response to glutamate in A cell. *a'* D-response to quisqualate.
b H-response to glutamate in B cell. *b'* H-response to quisqualate. The quisqualate responses were more potent than those to glutamate and to aspartate. Temperature 21 °C.