chanisch-rheologischer Kurven von Knorpelproben aus arthrotisch veränderten Gelenken verspricht neue Ansätze für die Klärung der Pathogenese der arthrotischen Gelenkveränderungen. Der für die Festigkeit des Knorpels wesentliche Bestandteil sind die kollagenen Fasern, die bereits in parallelsträhniger Form unter uniaxialer longitudinaler Zugbeanspruchung das rheologische Verhalten eines viskoelastischen hochpolymeren multifilen Gebildes zeigen[3–5]. Im hyalinen Knorpel sind die kollagenen Fasern in die hochvisköse Grundsubstanz eingebettet und haben zudem einen geometrisch komplizierten Verlauf. Aus diesem Sachverhalt ergibt sich ein mechanisches System des Knorpels, das nicht mit elementaren Gesetzen der Mechanik erklärbar ist.

Insgesamt haben die Versuche am hyalinen Knorpel das komplexe mechanische Verhalten dieses Gewebes gezeigt, das unter Berücksichtigung der Rheologie und Physik Hochpolymerer mit technologischen Methoden dargestellt werden kann. Besondere Beachtung verdienen die dem eigentlichen Versuch vorausgehenden mechanischen Belastungsarten («preconditioning»), die je nach Länge der zwischengeschalteten Pause einen Einfluss auf den eigentlichen gewebsmechanischen Versuchsablauf haben. Konstant kraftbegrenzte zyklische Belastungen sind nach Massgabe der Vorbelastungen reproduzierbar. Die Form der Kraftrückgewinnkurven und das Ausmass des Kraftrückgewinns (mechanische Erholung) sind abhängig von der Entlastungshöhe. Nach konstanten Entlastungsamplituden in verschieden hohen Kraftbereichen entstehen Relaxationen, isorheologische Strekken mit Sekundärrelaxationen oder Kraftrückgewinnkurven in Abhängigkeit von der Höhe des Kraftbereiches, in dem die axiale Deformation konstant gehalten wird.

Summary. Experiments on hyaline cartilage have demonstrated the complex mechanical behaviour of this tissue, which can be delineated with consideration of the rheology and physics of high polymers with technological methods of testing for organic materials. The mechanical loadings preceding the actual test (preconditioning) have, according to the length of the intervals, an influence on the actual histomechanical test. Constant cyclic loadings of limitted force are reproducible according to the degree of preconditioning. The shape of force-recovery curves and the size of mechanical recovery (force regain) depend on the extent of unloading. After constant amplitudes of unloading within different fields of force, there occur relaxations, isorheological straight lines with secondary relaxations or force recovery curves dependent on the level of the field of force in which the axial deformation is kept constant.

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[14] Frau J. GEESE und Fräulein A. KLARE danken wir für die bereitwillige und intensive technische Hilfe.
[15] Die Untersuchungen wurden ermöglicht durch die Unterstützung der Stiftung Volkswagenwerk.

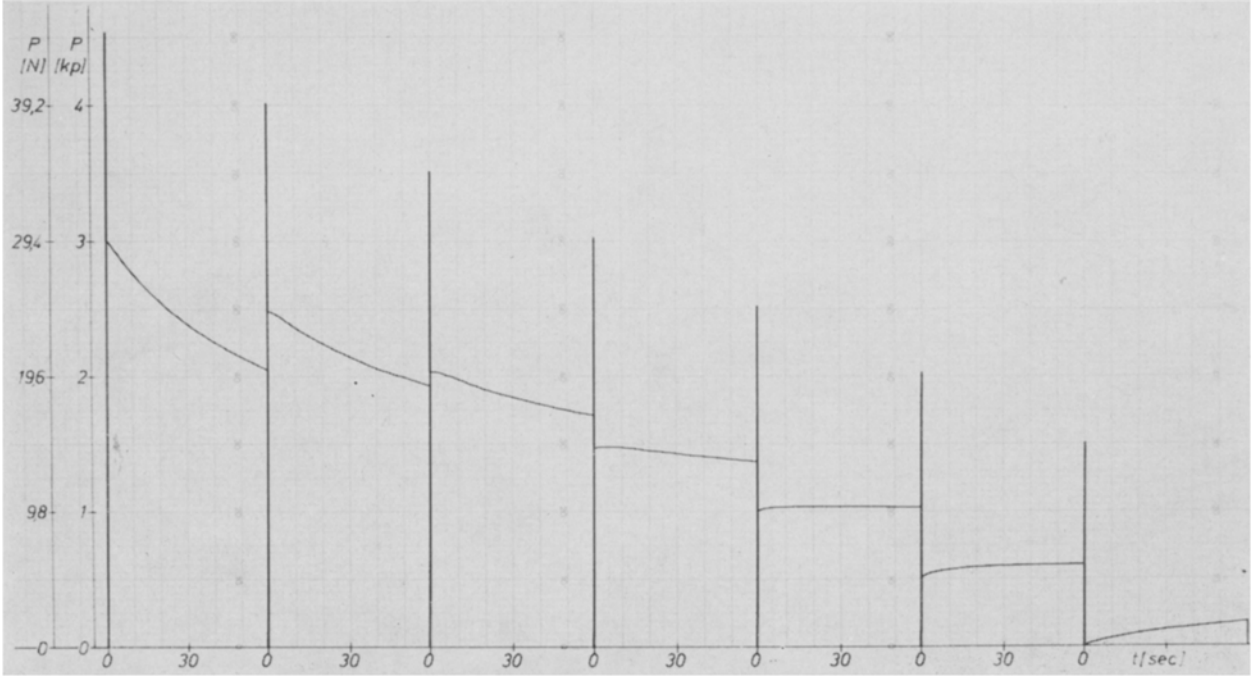

Fig. 3. Relaxationen und Kraftrückgewinnkurven nach konstanter Entlastungsamplitude und schrittweise erniedrigter Druckkraft. Selektivdarstellung. Rippenknorpel vom Rind. 1 Zylinder, Höhe H = 4,1 mm, Durchmesser D = 4,1 mm. Das Gewebe war bis zu den mittleren Kräften des Versuchs vorbelastet worden («preconditioning»). Druckplattengeschwindigkeit (Längenänderungsgeschwindigkeit) $v_{\Delta L}$ = 1,7 mm/min. Registrierpapiervorschubgeschwindigkeit v_t = 60 mm/min. Gerät 1361.

Selektive Freisetzung des hyperglykämischen Faktors aus den Corpora cardiaca von *Periplaneta americana* in vivo

In einer früheren Untersuchung konnte gezeigt werden, dass die beiden Neurohormone, nämlich Neurohormon D[1] und der hyperglykämische Faktor[2], durch In-vitro-Stimulation der N.c.c. I oder II aus den Corpora cardiaca selektiv ausgeschüttet werden[3]. Reizung von N.c.c. I führt zur Ausschüttung des herzanregenden Neurohormons D, Reizung des N.c.c. II bewirkt die Ausschüttung des hyperglykämischen Faktors. Die durch Reizung der beiden Nerven verursachte Hormonausschüttung wird zudem durch verschiedene Pharmaka reguliert[4].

In Beziehung zu den In-vitro-Ergebnissen wurde die Hormonfreisetzung aus den Corpora cardiaca von *Periplaneta americana* in vivo geprüft. Hierzu wurden den Versuchstieren (männl. Tiere 10 Tage nach Adulthäutung) getrennt entweder N.c.c. I oder N.c.c. II durchschnitten. Die Entnahme der Hämolymphe zur Trehalosebestimmung erfolgte vor dem Versuch und dann 1, 2 und 4 Tage nach der Operation. Nach Abschluss der Einzelversuche konnte mit der Präparation sichergestellt werden, dass eine einwandfreie Nervendurchtrennung vorlag. Nur solche Tiere kamen zur Auswertung. Für den Vergleich der Ergebnisse ist weiterhin wesentlich, dass die Trehalosebestimmungen für die Einzeltiere fortlaufend in den hier genannten Zeitabschnitten vorgenommen werden konnten. Zur Trehalosebestimmung in der Hämolymphe wurde die aus dem Herzen entnommene Probe mit 1 *N* HCl 40 min bei 116° bis 119 °C in abgeschlossenen Ampullen hydrolysiert, anschliessend die HCl im Vakuum über NaOH vom Hydrolysat entfernt. Die Bestimmung der entstandenen Glukose erfolgte mittels der *o*-Toluidintechnik, die Messung am Spektrophotometer bei 630 nm.

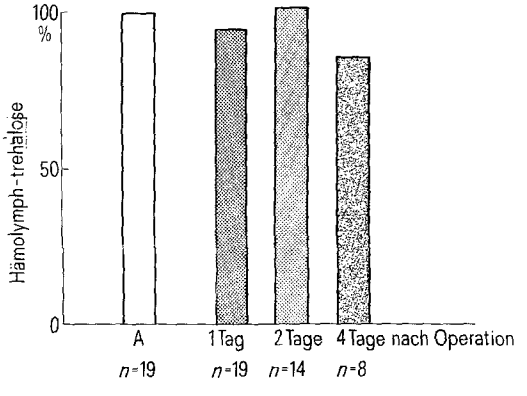

Fig. 1. Übersicht über die Werte der Hämolymphtrehalose von *Periplaneta americana* nach Durchtrennung von N.c.c. I 1 Tag, 2 Tage und 4 Tage nach der Operation im Vergleich zu den Ausgangswerten. Den Einzeltieren wurden jeweils vor der Operation und an den genannten Tagen nach der Operation Hämolymphe für die Trehalosebestimmung entnommen. Die Werte an den verschiedenen Tagen nach Durchtrennung von N.c.c. I zeigen keine signifikanten Unterschiede zu den Ausgangswerten. Die Säulendiagramme stellen die Mittelwerte der *n*-Zahl von Einzelversuchen dar.

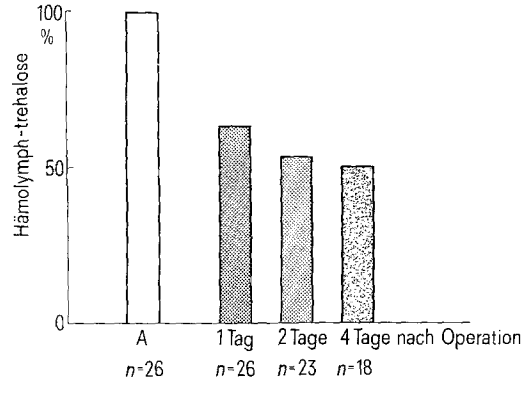

Fig. 2. Übersicht über die Werte der Hämolymphtrehalose von *Periplaneta americana* nach Durchtrennung von N.c.c. II 1 Tag, 2 Tage und 4 Tage nach der Operation. Behandlung der Versuchstiere wie in Erklärung zu Figur 1 angegeben. Nach Durchtrennung von N.c.c. II ist ein deutliches Absinken der Trehalose in der Hämolymphe in Vergleich zu den Ausgangswerten festzustellen.

Die Ergebnisse nach Durchtrennung des N.c.c. I sind zusammengefasst in Figur 1, diejenigen nach Durchtrennung des N.c.c. II in Figur 2 dargestellt. In beiden Fällen wurden die ermittelten Trehalosewerte der Hämolymphe der Versuchstiere prozentual auf die Werte der Kontrolltiere bezogen. Es ist klar erkennbar, dass die Durchtrennung des N.c.c. I die Trehalosewerte unbeeinflusst lässt. Dagegen erfolgt ein eindeutiges Absinken der Werte nach Durchtrennung des N.c.c. II. Beide Befunde stehen in guter Übereinstimmung mit den In-vitro-Ergebnissen. Hieraus kann die Schlussfolgerung gezogen werden, dass die Ausschüttung des hyperglykämischen Faktors aus den Corpora cardiaca in vivo selektiv über den N.c.c. II reguliert wird. Dabei sind, wie In-vitro-Experimente ergeben haben, adrenerge Faktoren beteiligt[4]. Eine selektive Hormonfreisetzung in vivo wurde auch für das diuretische Hormon bei *Schistocerca* allerdings im Gegensatz zur Regulierung des Blutzuckers nachgewiesen[5].

Summary. Sectioning of N.c.c. II of the corpus cardiacum of *Periplaneta americana* reduces significantly the concentration of Trehalose in the haemolymph. Sectioning of the N.c.c. I has not this effect. The results of individual sectioning of N.c.c. I and N.c.c. II demonstrate that selective release of the hyperglycaemic neurohormone from the corpora cardiaca in vivo is regulated by the N.c.c. II.

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5. Februar 1974.

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Utilization of a Cellular Calcium Pool for Contraction of the Human Myometrium

Mechanical activity of smooth muscle, like that of skeletal muscle, is regulated by changes in the level of free Ca ions in the myoplasm[1,2]. Stimulants and depressants of smooth muscle appear to act by elevating and lowering the myoplasmic Ca concentration. Various proposals have been made with regard to the source of the Ca ions that enter the cytoplasm.

Acetylcholine and other stimulants of the myometrium may elevate myoplasmic Ca by increasing the permeability of membrane to external Ca, by molilizing bound Ca from cellular stores or by a combined effect of the two processes[1,2]. In spite of an early demonstration that contractile responses by drugs could be elicited from depolarized smooth muscles in Ca free solutions and of other data in support of a cellular pool of Ca[3], the existence of an intracellular store of the activator Ca in smooth muscles is not unequivocally accepted[4–6]. The results presented here give strong evidence for the existence of a cellular calcium pool in the human myometrium from which Ca can be mobilized by acetylcholine to induce contraction.

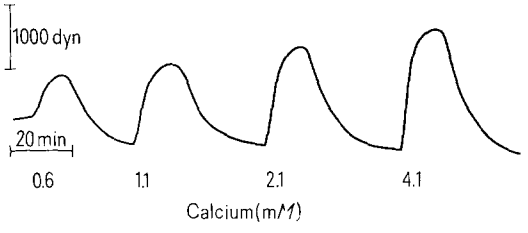

Fig. 1. Contractile response of K-depolarized human myometrium to varying Ca concentrations in Krebs-Ringer medium.

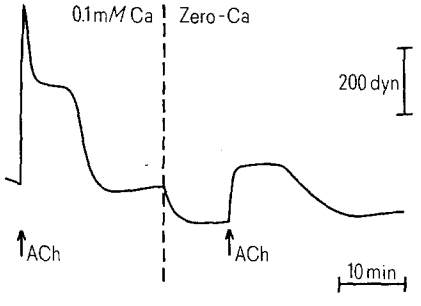

Fig. 2. Response of K-depolarized human myometrium induced by acetylcholine in 0.1 mM (low Ca) and zero-Ca media. Acetylcholine (ACh) concentration was 10^{-4} g/ml.

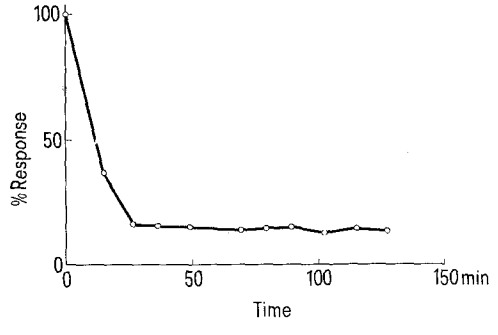

Fig. 3. Repeated contractions of K-depolarized human myometrium in zero-Ca medium. At 0 min the bath solution was changed from low Ca to zero-Ca. Responses were induced by ACh (10^{-4} g/ml) at symbols (○) in the figure.

Myometrial strips (0.5 × 3 × 15 mm) from non-pregnant tissues removed at hysterectomy were mounted in a 20 ml organ bath filled with Krebs-Ringer bicarbonate solution. The composition of this solution was mM: NaCl 115, KCl 4.63, $CaCl_2$, 2.47, $MgSO_4$, 1.16, $NaHCO_3$, 21.9, NaH_2PO_4 1.16, glucose 5.0.

Two other solutions were used in these experiments and are referred to as low Ca where Ca in the Krebs-Ringer solution was reduced to 0.1 mM, and zero-Ca where Ca was omitted but 1 mM EGTA was added. In the depolarizing medium, all of the NaCl was replaced by KCl.

Mechanical responses were recorded isometrically at 37 °C. Illustrations are traced from original recordings, omitting the periods of washings and solution changes.

When K-depolarized myometrial strips were exposed to increasing Ca concentrations (0.6–4.1 mM), graded mechanical responses were obtained (Figure 1). This clearly indicates that external Ca can directly cause contraction of the depolarized myometrium, which is essentially in agreement with the results obtained by EDMAN and SCHILD[3] on depolarized rat uterus. Figure 2 compares the responses of the depolarized myometrium induced by acetylcholine in zero-Ca and Ca-containing solution. The fact that the responses to acetylcholine were considerably faster (Figure 2) than those induced by the addition of Ca (Figure 1) suggests that a cellular pool of Ca is being utilized in the former case. This is further supported by the results in Figure 2 showing that acetylcholine was able to induce contraction in zero-Ca medium (which contained 1 mM EGTA). Changing the medium from low Ca to zero-Ca resulted in 67% decline of resting tension. Significant response to acetylcholine was obtained in zero-Ca medium. This response was considerably reduced when compared with that obtained in low Ca medium (Figure 2). The type of response obtained in zero-Ca medium was also different from that in low Ca medium. In Ca-containing medium, a sharp peak followed by a sustained contracture (a biphasic response) was observed (Figure 2), while in zero-Ca medium the peak was abolished and only the sustained contracture (a monophasic response) was obtained.

EDMAN and SCHILD[3], in their study on the depolarized rat uterus, observed a loss of response in successive contractions induced by acetylcholine in a Ca-free medium. These authors observed that after 1 h, when several repeated contractions by acetylcholine had been induced, the responses became insignificant. A similar loss of response to stimulants of other smooth muscles in Ca-free medium has been reported (e.g.[1,2]). In fact certain mammalian smooth muscles failed to respond to acetylcholine in Ca-free medium[7]. Figure 3 shows that the mechanical response

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induced by acetylcholine in zero-Ca medium remained unchanged for 2 h, in which time 9 successive contractions were induced. It appears therefore that not only different smooth muscles differ in their Ca binding properties but the same muscle from different species may differ in this respect[8,9]. The present results, showing that there was no decline in response in successive contractions induced by acetylcholine in zero-Ca medium, indicate that Ca which is mobilized by acetylcholine is located either intracellularly or on the inner surface of the cell membrane. This Ca, during its mobilization for contraction, does not appear to leak out into the extracellular medium, since in that event the diffused Ca would be captured by EGTA in the external medium (see methods) and would not be available for the consecutive contractions (Figure 3). Alternatively, the cellular calcium pool is enormously greater than the fraction mobilized during a contraction. No information on the precise location of this Ca or the mechanism of its release and re-accumulation can be given. Preliminary experiments on isolated mitochondria and microsomes from this tissue showed that acetylcholine in the concentration used in the present experiment had no effect on Ca binding or release by these fractions[9,10,11].

Zusammenfassung. Im K-depolarisierten Myometrium ist die mechanische Aktivität durch die extrazelluläre Ca-Konzentration graduierbar. Zugabe von Acetylcholin in die Ca-freie, depolarisierende Lösung ergibt mechanische Spannungsentwicklung des Myometriums.

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Temperature Responses of Exercizing Dogs to Infusion of Electrolytes

In man, equilibrium levels of rectal temperature (T_{re}) during exercise are highly correlated ($r = +0.71$) with plasma sodium and osmotic concentrations, but are essentially unrelated ($r = +0.34$) to variations in plasma volume[1-3]. This ion-osmotic factor appears to act by controlling sweat gland function; that is, the rate of sweating is inversely proportional to the plasma ionic-osmotic concentration. It is not clear if the ions act directly on the sweat glands or if the action is primarily on the hypothalamus. Hasama[4] was one of the first to observe the relationship between plasma ionic concentration and body temperature in resting animals and more recently Myers and Yaksh[5] found that solutions of 3 to 5 times normal concentration of sodium injected into the cerebral ventricles of monkeys increased resting temperature and similar concentrations of calcium decreased body temperature. They postulated that the setpoint for body temperature during rest was determined by the Na^+/Ca^{++} ratio. In the present study the effect of infusions with solutions of various ionic and osmotic composition on exercise temperature responses was studied in dogs, who do not regulate their temperature by sweating.

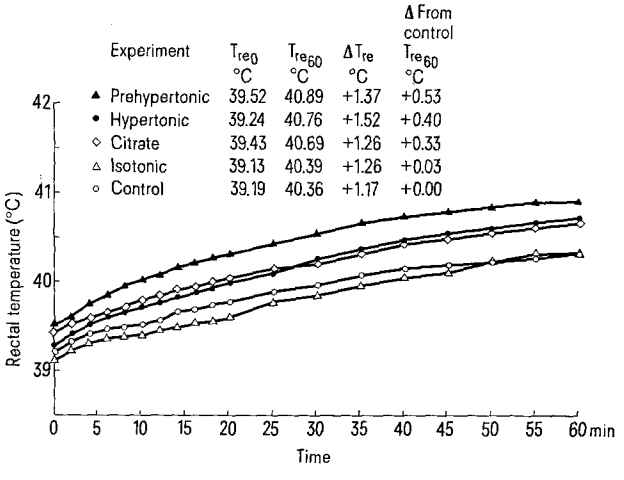

Fig. 1. Average (± S.E.) rectal temperature responses at rest (0-min) and during 60 min of exercise for the 5 experiments.

Material and methods. Six, male, mongrel dogs (11.6 to 27.2 kg) maintained on a standard diet were used. 24 h before each experiment they were deprived of food, but had free access to water. In all experiments the dogs performed 1 h of standard treadmill exercise (1.2 m/sec; 12° slope). Their T_{re} was measured with a thermistor (Electronic) inserted 13 cm. There were 5 different experiments performed on each dog: a) hypertonic: continuous i.v. infusion of NaCl solutions (6.7% to 10.0%, and 110 to 134 ml at a mean rate of 3.6 ml/min (range 2.6 to 4.1) was given for the first 20 min of exercise and 1.1 ml/min (range 0.7 to 1.3) for the final 40 min; the rate was proportional to the size of the estimated extracellular fluid volume designed to raise plasma osmolality to about 320 and 330 mOsm/l; b) isotonic: 0.9% NaCl was infused during the run at the same rate as in (a); c) prehypertonic: the same osmotic load as in (a) was infused during 30-min starting 1 h before exercise; d) control: 1 h of exercise with no infusion; and e) citrate: 3.8% sodium citrate was injected i.v. at a dose of 1.8 ml/kg immediately before exercise.

The infusions were given with a Unipan (Model 304) peristaltic pump. Plasma osmolality (Fiske Osmometer), plasma proteins (Biuret method), plasma sodium (Zeiss flame photometer), and micro-hematocrit (Unipan Model 316) were measured on the 0, 5, 15, 25, 40 and 60 min venous blood samples. The results were analyzed by the *t*-test for paired data with the level of significance ($P \leq 0.05$).

Results and discussion. At the end of one hr of exercise, the highest mean T_{re} was attained following prehyper-

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tonic infusion, the next highest was hypertonic, then citrate, as compared to the isotonic and control T_{re} (Figure 1). The ΔT_{re} in the prehypertonic and citrate experiments were lower than in hypertonic because their 0-min values were elevated 0.2 to 0.3 °C. The prehypertonic T_{re} was higher ($P \leq 0.05$) than isotonic and control T_{re}. Mean T_{re} increases during exercise were higher ($P \leq 0.05$) in the prehypertonic experiment compared with those in the control experiment between 12 and 40 min during the run, but not thereafter due to the increasing variance between dogs.

In the hypertonic and citrate experiments T_{re} increases during exercise were distinctly higher than those in the control and isotonic experiments in 4 out of 6 dogs, however, the mean differences were not statistically significant.

The plasma protein concentrations and hematocrit (Hct) reflect the changes in plasma volume (PV): with a constant red-cell volume, a one-unit change in Hct is equivalent to approximately a 4% change in PV[6]. Prehypertonic Hct was low ($P \leq 0.05$) due to the prior infusion and indicated an expanded PV that decreased as the exercise progressed. Hypertonic Hct at 0-min was at the normal level and dropped with infusion during exercise to the prehypertonic level; this also indicated an increase in PV. The citrate and isotonic Hct were essentially constant during exercise, while the control Hct rose slightly (Figure 2). At 0-min the prehypertonic protein concentration was depressed ($P \leq 0.05$) but was not different from those found in the other four conditions at 25 min (Figure 2). Hypertonic proteins were significantly lower than those in the other 4 experiments at 25 min. There was no significant difference in proteins among the 5 groups between 40 and 60 min. In agreement with the Hct data, these results indicate that following prehypertonic infusion, plasma volume was elevated initially and declined progressively during exercise, while with hypertonic infusion PV increased during the first 25 min of exercise and then began to decrease during the last 35 min when the rate of infusion was reduced. It appears that T_{re} was not influenced by these variations in PV (Figure 1).

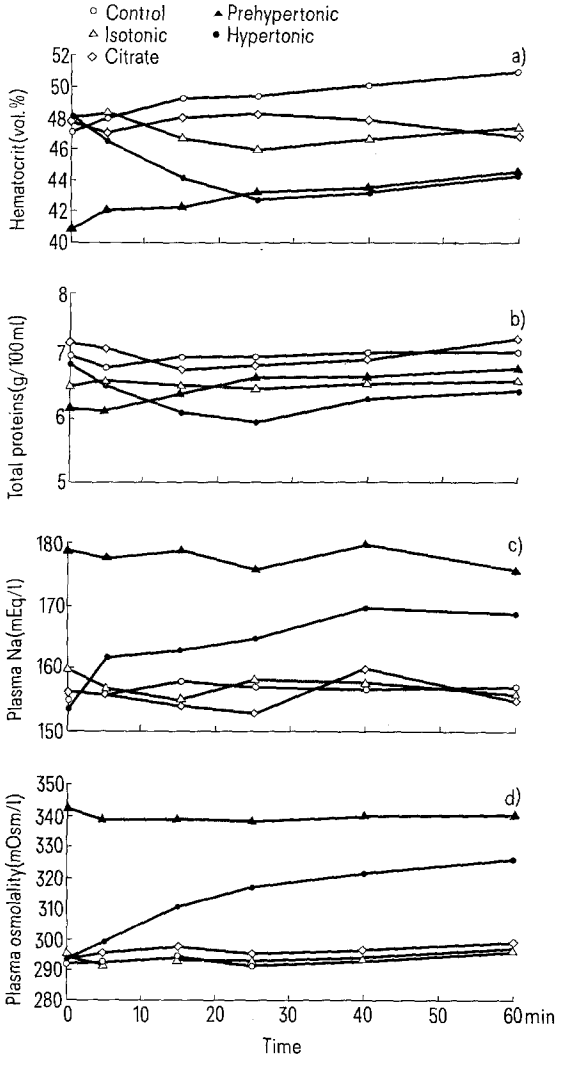

Fig. 2. Average (± S.E.) values for hematocrit and plasma sodium, osmolality and total proteins a rest (0-min) and during 60 min of exercise for the 5 experiments.

During exercise, plasma Na concentrations (Figure 2) followed the changes in plasma osmolality in all 5 experiments. The higher T_{re} in the prehypertonic and hypertonic experiments were associated with higher plasma Na and osmolality. Since a constant exercise load results in a constant heat production for each animal, the proposed explanation is that the ion-osmols act to vary heat dissipation. That is, the higher the plasma osmotic concentration, or cellular dehydration, the greater the inhibition of heat dissipation, and the higher the core temperature. It remains to be determined if hyperosmolality inhibits peripheral blood flow, the panting response, or both. It is clear that the ability to sweat is not a necessary component of the ion-osmotic mechanism.

In the citrate experiment Na and osmotic concentrations during exercise were constant and at the same level as the isotonic and control values. Therefore, the higher T_{re} in these experiments are due to factors other than the Na or osmotic concentrations, perhaps to a decrease in the Ca^{2+} concentration and subsequent increase in the Na^+/Ca^{2+} ratio. These results suggest an association between plasma Na^+ and Ca^{++} within the *normal physiological range* and the control of body temperature during exercise.

Zusammenfassung. Bei Hunden im Training steigt nach Infusion hypotonischer Salzlösungen die mittlere Mastdarmtemperatur stärker an als bei unbehandelten Tieren. Gleichzeitig wird ein starker Anstieg des Plasmanatriums und damit verbunden eine erhöhte Osmolalität des Plasmas gefunden. Wieweit diese beiden Faktoren oder einer von ihnen für die Erhöhung der Rectaltemperatur verantwortlich sind, wird versucht aufzuzeigen.

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19 November 1973.

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Kininogenase in Urine Produced by Isolated Perfused Rat Kidneys

Although several reports show that urinary kallikrein differs from plasma kallikrein and resembles renal kininogenase[1-4], no definitive evidence has been provided as to whether the urinary enzyme represents the clearance of a blood kininogenase or is a product elaborated and/or stored by the kidneys. Experiments here described show the occurrence of kallikrein in the urine produced by isolated rat kidneys, perfused with adequate fluids which do not contain either kininogenase or its precursors.

Methods. Adult rats (300–400 g) were anesthetized with diethyl-barbiturate. After the injection of heparin (10 mg in 0.1 ml), polyethylene catheters connected with the perfusion system, were introduced into the cava vein and aorta. Both vessels and their branches were rapidly ligated, leaving free the short segment corresponding to the renal arteries and veins emergences in order to irrigate both kidneys with the perfusion fluid. The kidney circulation was interrupted for only 1–2 min (time required for ligature) and then artificial circulation was set in motion. The perfusion system, which can be used as a closed or open model, was set up in a similar way as that described by KRAHÈ et al.[5]. A rotating flask where a mixture of O_2 (95%) and CO_2 (5%) was continuously flowing was used as fluid reservoir and oxygenator. Two different perfusion fluids were used: 1. Tyrode-dextran solution (1 l contained 8 g NaCl, 0.2 g KCl, 0.24 g $CaCl_2$, 1 g $MgCl_2$ 6 H_2O, 1 g $NaHCO_3$, 1 g D-glucose) and 40 g dextran (m.w. 60,000) plus rat red cells (TDR) 2. called TAR was similar to TDR, but dextran was substituted by 5% human albumin (U.S.P. Squibb and Sons). Either to dextran or albumin fluids, washed rat red cells were added in order to obtain a final hematocrit of 30–35%. During the first 10–15 min of perfusion, oxygenated fluid purposely lacking red cells was pumped to the kidneys in order to wash out the blood remaining in these organs. From then on washed rat red cells were added to the perfusing fluid. The pulsatil perfusion pump was regulated so as to maintain a mean blood pressure of 90–120 mm Hg (systolic pressure of 120–140 mm Hg) on the arterial side, which provided a flow of 5–8 ml of perfusate per min. The perfusion pressure was continuously recorded through a Statham transducer P23 connected to a Grass polygraph. The outflow was checked every 15–20 min measuring the fluid volume draining from the kidneys. With that flow, a drop of 8–12% O_2 saturation was recorded between arterial and venous sides. Urine produced during the experiment was collected through an endwelling bladder catheter after a thoroughly washing the cavity with saline; 17 experiments using the closed system and 3 using open system were performed. In each experiment, lasting from 60 to 180 min, 2 or 3 samples of urine (0.2 ml to 0.8 ml/h) were collected.

The occurrence of a kallikrein-like enzyme in the urine was investigated by chemical and biological approach, according to the method already described for renal kininogenase identification[6].

Results and discussion. Both with TAR or TDR, the following results were obtained: 1. The urine samples display direct oxytocic effect upon rat uterus, as normally urine does. This activity does not diminish with dialysis. Effect equivalent to 10 ng of bradykinin were recorded with 0.05–0.15 ml of urine, when introduced into a bath of 20 ml capacity, where the isolated rat uterus was immersed. 2. Kininogenase activity was easily demonstrated incubating for 2 min, 0.02 to 0.08 ml of urine either with kininogen II (Figure) or kininogen I at pH 7.4. These substrates were prepared from rat plasma by the method of JACOBSEN[7]. The substance produced during incubation induces rat uterus contraction similarly to kinins; its oxytocic activity is destroyed by chymotrypsin, but not by pepsin. 3. The addition to the urine of 200–500 IU of aprotinin (Trasylol, Bayer) blocks its kininogenase activity. 4. DFP added to the urine (final concentration 0.25 *M*) produced a striking inhibition of

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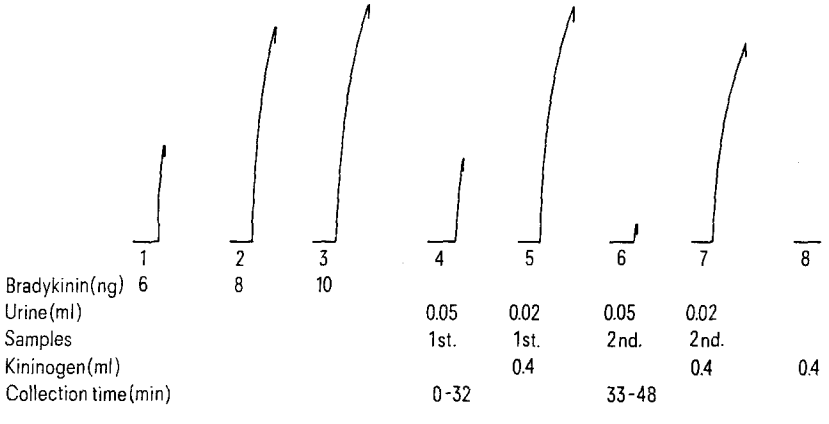

Effect of 2 urine samples upon isolated rat uterus. In 1, 2 and 3, 6, 8 and 10 ng bradykinin were introduced in the bath; in 4, 0.05 ml of urine (first sample collected between 0–32 min of perfusion); in 5, a mixture incubated for 2 min (pH 7.4) of 0.02 ml of the first urine sample plus 0.4 ml of kininogen II; 6, 0.05 ml of the second urine sample (collected between 33–48 min; in 7, an incubated mixture of 0.02 ml of urine plus 0.4 ml kininogen II; in 8, 0.4 ml kininogen II.

both the direct oxytocic effect and kininogenase activity of the urine. 5. Soyabean antitrypsin also inhibits at a high concentration (200–500 µg for 0.1 ml of urine) this kininogenase activity, but ovomucoid (Sigma Chemicals Co.) does not. 6. Pepstatin, a polypeptide which inhibits renin but not kallikrein activity, does not hinder kininogenase effects. The kallikrein activity of the urine produced during the perfusion period was 10–30-fold lower compared with the urine voided by the rat before the experiment. During the experiment, O_2 consumption and vascular resistance were not significantly changed, but a progressive decrease in kallikrein concentration was observed in the formed urine. On this question further studies will be required to establish whether some biochemical impairment or other factors are involved. The small amount of urine collected (not greater than 0.6 to 1.8 ml in the experimental period) limited the possibility of a chemical purification of the enzyme. The results tend to support the assumption that kallikrein found in the normal urine is also produced by the kidney and is not an enzyme cleared from the circulating blood.

Résumé. L'urine produite par les reins isolés du rat perfusés à pression normale pendant 60–180 min avec des liquides oxygenés ayant en suspension des globules rouges contient une kininogénase qui a les mêmes propriétés que la kallikréine de l'urine produite en conditions physiologiques.

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Effect of Starvation on Blood Glucose and Nonprotein Nitrogen Levels of the Fish *Clarias batrachus*

Starvation effects the normal body metabolism and prolonged starvation may even cause death of the animal. A decline in various body constituents of fish, following experimental starvation, have been reported by various authors[1–3]. Studies, following starvation, on the blood glucose and nonprotein nitrogen (NPN) levels, etc. have also been made[4–10]. This paper deals with the results obtained for the fresh-water cat fish *Clarias batrachus*, following starvation up to 150 days.

Materials and methods. Normal, well fed *Clarias batrachus*, fully acclimatized to laboratory conditions were used. Right from the beginning of the experiment the starving fish were kept in separate aquaria and were not given any food for the entire period of starvation. Even aquatic plants were removed and nothing except pebbles and bed of river-sand was left in the aquaria. Water was changed twice a week throughout the experimentation period and this possibly removed even the naturally developing micro-fauna and flora and also accumulating toxic waste products of the fish. Control fish were kept in separate aquaria and were given minced goat liver, earthworms and snails on alternate days.

The experiment was started in the month of November and concluded in the month of April. The starvation was prolonged up to 150 days and observations were made on 1st, 10th, 30th, 90th and 150th day of starvation. On the first day only 5 fish of the control batch were examined. In subsequent periods, 5 fish of control group were also examined along with the starved fish, to counter the effects of seasonal variations, etc. Thus 25 fish of the control group and 36 starved fish were examined in this experiment.

For taking blood, the fish was carefully taken out of the aquarium with the help of a small hand net, immersed in a jar containing 1.5% paraldehyde solution. It took about 2 min to make a fish senseless. Immediately the fish was taken out, wiped dry with a turkish towel and put on a disection tray. Its caudal vein exposed just behind the anal region and blood drawn in a syringe fitted with a 20 gauze needle. Exactly 1 ml blood was deproteinized using zinc hydroxide-barium-sulphate procedure (OSER[11]). Blood glucose and NPN determinations were made following the Nelson-Somogyi and Folin-Wu methods, respectively (OSER[11]). After the blood was drawn, gut contents and viscera of both the control and starved group of fish were examined. No mortality of these fishes occurred during the entire period of starvation.

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Effect of starvation on blood glucose and NPN levels of the fish *Clarias batrachus*

Status and No. of observations	Glucose and standard deviation (mg/100 ml)	NPN and standard deviation (mg/100 ml)
Control (25)	63.3 ± 11.7	38.9 ± 7.7
Post starvation		
10th day (8)	59.8 ± 13.2	35.6 ± 6.0
30th day (8)	53.5 ± 11.7	31.1 ± 7.7
90th day (10)	44.3 ± 12.5	27.3 ± 7.3
150th day (10)	32.0 ± 9.1	20.5 ± 4.8

Results and observations. The normal blood glucose level in the control fish was found to be 63.3 ± 11.7 mg 100 ml (Table). The level showed a fall as the starvation commenced. A direct correlation was found to exist between the blood glucose level and period of starvation, i.e. the level went on falling as the period of starvation was prolonged. Though the changes in blood glucose and NPN level (38.9 ± 7.7 mg/100 ml) in the control group fish were statistically not significant by the end of the 10th day of starvation ($P>0.5$), nevertheless a fall in the two values was observed. This depletion of the 2 constituents of the blood became highly significant on the 30th day ($P<0.01$) of starvation. The values of glucose and NPN levels in the blood of starving *Clarias batrachus*, on the 150th day, the last day of the experiment, were 32.07 ± 9.1 mg/100 ml and 20.5 ± 4.8 mg/100 ml respectively. It was calculated that a fall of 49.3% and 47.3% had occurred in the blood glucose and NPN levels respectively, by the end of the 150th day compared with the control values.

Discussion. A perusal of the results obtained (Table) clearly shows that marked depletion in the blood glucose and NPN levels occurred throughout the period of 149 days of starvation. AL-GAUHARI[6] did not observe any change in blood glucose level of the fish *Clarias lazera*, even after 4, 5, 6 and 7 months of fasting period. However, HANNA[12] noted a fall of 60% in the glucose level of the same species after 7 months of starvation, although the value did not change during the first 4 months. PHILLIPS et al.[5], on the contrary, observed a decrease in blood glucose level of the fish *Salvelinus fontinalis* in the first 3 days, after which the level was almost steady. Simillary the blood glucose level of *Gadus morhua* declined from 108 mg/100 ml to 72 mg/100 ml in the first 37 days but remained at this level after 51 days at 6.5 °C[13]. Surprisingly, the blood glucose level appeared unaffected, even after 3 weeks of starvation in *Myxine glutinose*[14]. KIERMEIR[4] observed that several species of fresh water teleosts, both active and sluggish, maintained their normal blood glucose levels during long periods of starvation. Interestingly, the active fish showed a very gradual decrease, while the sluggish ones exhibited a remarkable constancy.

BENTLEY and FOLLETT[15] observed a definite fall in the blood glucose level of the lamprey after 5 months of starvation. SUNDARARAJ et al.[16] noticed a definite and continuous fall in the blood glucose level of the Clupeoid fish *Notopterus notopterus*, but only after 48 h of starvation, during which a hyperglycemic peak was found after 24 h, while HOCHCHKA and SINCLAIRE[17] did not notice any change in the blood glucose level of *Salmo gairdnerii*, even after 14 days of starvation, though its liver glycogen had fallen considerably.

Studies on blood NPN level are not many[8], a slight rise in serum NPN level following 3–4 days of starvation was found in the eel *Anguilla japonica*. However, the present study shows that there was a parallel fall in blood glucose and NPN levels of the fish *Clarias batrachus* during starvation, the fall appeared to be very prominent as compared with the control values.

Conclusions. From the foregoing discussions it is evident that contradictory results have been obtained by various authors, on the blood glucose and NPN levels of fishes. It appears strange that many workers did not find any change in the blood glucose level of several species, even after quite long periods of starvation, since starved animal should ordinarily show little or more depletion in its blood glucose level. However, the present observations, like those of many workers, show that a definite fall in the blood glucose and NPN values, from the control levels of 63.3 ± 11.7 mg/100 ml and 38.9 ± 7.7 mg/100 ml to 32.0 ± 9.1 mg/100 ml and 20.5 ± 4.8 mg/100 ml respectively occurred by 150th day of starvation.

Zusammenfassung. Untersuchungen über das Verhalten des Blutzuckers nach längerem Nahrungsentzug bei Fischen.

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The Ability of Cod (*Gadus morhua*) to Orient Towards a Sound Source

The acoustic perception of the direction of a sound wave (sound localization) in fish is theoretically problematic[1–3], but there is quite a lot of evidence that several sharks[4] and some teleosts[5–8] possess this sensory ability. However, for several reasons, either incomplete experimental designs or inadequate sound fields caused by improper boundary conditions, almost none of these experiments provided a really decisive proof for acoustic localization at several meters from the sound source, e.g. no specific alternative explanations have been investigated[9].

The present experiments[10] meet the requirements to answer the following questions: Is cod able to determine the direction of a sound? If so, is the labyrinthine system involved or the lateral-line system (hypothesis of VAN BERGEIJK[1])?

Under a raft in the middle of an almost circular fjord (local depth 35 m; 'diameter range' 300–400 m) a round netting cage, altitude 17 cm, was suspended at a depth of

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4.75 m (top). By means of netting screens in the cage, a radial corridor was made with an entrance near the circumference and with an ending in the centre. A cod, length about 30 cm, was reinforced to perform a closed track through the corridor (operant). When the cod swam in the corridor, a transient free switched, interrupted pure tone of 75 Hz (18 dB re 1 µbar) was presented, when it was in the correct position and orientation to make a choice out of 4 possible sound directions (I, II, III and IV numbered counterclockwise). For this object 4 sound projectors were hanging in a circle (radius 5.3 m) around the centre of the cage each 60° apart. The outermost stimulus alternatives I and IV were 90° to the right and the left, respectively, of the fish when leaving the corridor.

The stimulation ended when a response of the cod was observed, or otherwise the observation period ended after 4.5 sec equal to 3 intervals (sound 0.75 sec plus pause 0.75 sec). Subsequently the fish was rewarded at the feeding place that was in line with the active sound projector. A directional response consisted of stopping locomotion with the pectoral fins (this pattern could be absent), followed by suddenly turning and swimming straight towards the lateral netting wall. Typically it was a correct choice: an oriented response towards the source. The responses were observed through a periscope and classified by an independent observer not aware of the stimulus direction. After the judgement, the fish was rewarded by the trainer. The 4 remotely operated, acoustically transparent food dispensers[12] were mounted in a cylindrial frame resting on the cage. The food consisted of feet of periwinkles. A cylinder of opaque PVC sheet (acoustically transparent) around the netting cage concealed the locations of the sound projectors from the eye of the fish.

Table I. Example of a stimulus response matrix

Response towards		I	II	III	IV
Stimulus type	I1	**6**	0	0	0
	I2	**5**	1	0	0
	II1	1	**5**	0	0
	II2	0	**7**	1	0
	III3	1	1	**5**	0
	III4	0	2	**3**	1
	IV3	0	0	0	**6**
	IV4	0	0	1	**5**

Table II.

Type: minus left pars inferior $N = 14$					Type: control animal $N = 44$				
	A[a]	B	C	D		A	B	C	D
I	1	1	1	1	I	5	5	1	0
II	0	0	2	1	II	0	6	4	0
III	4	0	0	0	III	0	1	12	0
IV	2	1	0	0	IV	0	0	3	7

[a] A = response towards I, etc.

During the observation series, the locations of the sound projectors (the pair 1 and 2) in the directions I and II could be interchanged and/or similarly the pair at the other side of the raft (3 and 4 in the directions III and IV). This procedure provided a test whether discrimination is based on inherent minute differences between the sound projectors (intensity, timbre). The choices of the fish can thus be classified in 4×8 different categories depending on the stimulus type.

Two subjects were conditioned successfully after about 30–70 trials (2 to 3 days). Table I presents the stimulus response matrix for cod G4. For various reasons, it was not possible to obtain a fixed number of observations in each row.

Since interchanging the positions in a pair of sound projectors was rather laborious, each of the four possible configurations was kept unaltered during a variable number of trials (range: 7–18), but the stimulus directions were always selected at random.

There were no indications for a conditioning on source specific cues[12] in the sequence of response observations, taken in the order of occurrence. Moreover, randomness could be accepted[12] for the sequence of successes and failures (runs test): a necessary condition for the presentation in a contingency table. Small sample tests showed that it is admissible to join the bold printed frequencies in Table I in common categories with equal stimulus directions (comparison of 2 binomial populations[13] for each direction). Similar results were obtained in another subject (G1); however, responses for stimuli from direction I had to be excluded from statistical analysis in G1, because it visited food dispenser I too little. If all categories are pooled by a similar procedure, a 4×4 table is obtained (3×4 in G1).

The discrimination of the bearing of the sound sources by the intact cod G4 is evident (binomial test for the dichotomy success and failure with the pessimistic null hypothesis $H_0: P\{\text{success}\} \leq 0.5$ for each considered direction; by combination of these tests H_0 is rejected if the sum S of all successes, irrespectively of the directions, assumes large values; in G1, the worst case, the outcomes were: $S = 25$, $p = 0.01$). Measurements of the acoustic pressure and the particle velocity confirmed the absence of specular reflections[11] (echoes; acoustic isotropy).

After severing[14,15] the nerve roots innervating the pars inferior of the left labyrinth in cod G4, the ability to discriminate the directions of sound was abolished (upper Table II) although the lateral-line system was still functioning. The prompt responses observed before the operation persisted, but a rapid extinction of performing the operant was observed. In the well-trained cod G1, all the procedures of the surgery[15] were carried out with the exception of the severing of the nerve roots. After the operation, the discrimination results were at least as good as before the operation (control experiment; Table). It is concluded that cooperation of both labyrinths is involved in directional hearing. The results contradict the unverified theory of VAN BERGEIJK[1].

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That cod probably possesses directional hearing has previously been stated[5,16]. CHAPMAN[16] has proved that sound perception in cod depends on the angle between the directions of a tone and a masking noise. Recently[17] it has been shown that the saccular microphonics in the haddock (*Melanogrammus aeglefinus*) exhibit a directional sensitivity, as has been expected since long[18]. The explanation of directional hearing is sought in the direct stimulation of the labyrinthine maculae[19,4,7] (not via a link with the swimbladder). However, in cod, indirect stimulation of the saccular otoliths is likely[20]. ENGER et al.[17] therefore suggest that stimulation of the maculae by re-radiated sound from the swimbladder is avoided (minimized) by proper orientation of (part of) the hair cells (insensitive to radial displacements emanating from the swimbladder).

Zusammenfassung. Im freien Schallfeld wurde in einer Belohnungsdressur beim Kabeljau (*Gadus morhua*) akustische Lokalisation nachgewiesen. Die Entfernung des Fisches von der Schallquelle betrug 5,3 m ($f = 75$ Hz). Ausschaltversuche zeigen, dass das Seitenorgansystem nicht wesentlich an der Schallrichtungsunterscheidung beteiligt ist.

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Einfluss von ATP in einer holidischen Diät auf *Myzus persicae* (Sulz.) (*Aphidina*)

Bei der Bearbeitung stoffwechselphysiologischer Probleme gewinnt die Ernährung der Versuchstiere mit einer holidischen (voll-synthetischen) Diät immer grössere Bedeutung. Die bei phloemsaugenden Insekten verwandten Nährlösungen orientieren sich an Phloemsaftanalysen diverser Pflanzen[1,2] und enthalten allesamt Verbindungen der Stoffklassen Kohlenhydrate, Aminosäuren, Vitamine sowie Spurenelemente[3,4]. Als Mass für die Güte der Diät wird ein möglichst hohes Gewicht nach definierter Lebenszeit, kurze Ontogenie und hohe Reproduktionsrate gewählt. Mit der phloemsaugenden Aphide *Myzus persicae* ist erstmalig der Nachweis gelungen, dass ATP in der Nahrung auch für phytophage Insekten von Bedeutung ist. Als Diät (kurz: ST-Diät) wurde eine speziell für diese Spezies optimierte Nährlösung[5] verwandt. Dieser Diät zugesetztes ATP (hier als Adenosin —5′-triphosphorsäure Dinatriumsalz) bleibt auch nach 10 Tagen bei 20 °C, 65% RLF und Dauerlicht gut nachweisbar (Boehringer Test, enzymatische Reaktion). Für die Versuche wurden an jungen Rettichpflanzen gezogene Virgines in Käfigen mit entsprechenden Diäten eingeschlossen. Nach je 24 h wurden die geborenen Larven gezählt und die Mütter in einen neuen Käfig überführt. Nach 4 Tagen hatten die an einer Diät mit 1,11 μM ATP saugenden Mütter ein um 9,4% höheres Gewicht als Mütter an der ST-Diät. Täglich wurden an der ATP-Diät 5,7 Larven/Imago (= 120%), an der ST-Diät 4,5 (100%) geboren. 11 Tage alte, auf den entsprechenden Diäten geborene Mütter zeugten bei einmaligem Diätwechsel nach 6 Tagen bis zu diesem Zeitpunkt auf der ST-Diät 2,6 Larven/Imago (100%), auf der ATP Diät 6,4 (245%). Die Larven erreichten ihr höchstes Körpergewicht bei 1,11 μM ATP in der Diät im Bereich von 0,44 bis 2,22 μM (Tabelle I).

Das Optimum liegt etwas über den im Phloem festgestellten ATP-Mengen: für 18 verschiedene Laubbäume wurde bis zu 0,59 μM[6], im Läuserüsselexsudat von *Salix* im Mittel 1,68 μM[7] und für die Monokotyle Yucca 1,22 μM ATP[8] gemessen. Die ATP-Konzentration ist im Sommer wesentlich geringer als im Frühjahr[6], steigt jedoch im Herbst wieder an[8]. Eigene Diätwahlversuche zeigen, dass ATP wie auch bei der blutsaugenden Tsetsefliege[9] als Phagostimulans in erhöhter Konzentration von Bedeutung ist. Vielleicht bevorzugt *M. persicae* einen relativ hohen ATP-Gehalt (vergleiche hierzu auch die geringe Populationsdichte der Aphiden im Sommer, hohe im

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Tabelle I. Beeinflussung des Körpergewichtes alatoider (geflügelt werdender) und apteroider (flügellos bleibender) Morphen 6 Tage alter *M. persicae* Larven durch ATP-Gaben in der holidischen Diät

Gewicht % Morphe	μM ATP in der Diät						
	0,00	0,35	0,44	1,11	1,67	2,22	4,45
Alatoid	100,0	104,4	110,9	111,1	109,4	106,0	102,6
Apteroid	100,0	105,0	107,0	110,6	108,1	109,7	104,4

Die mittleren Körpergewichte aller in 4 Tagen geborener Larven sind prozentual auf das Körpergewicht von Larven auf ATP-freier Diät bezogen.

Tabelle II. Einfluss der Dauer künstlicher Ernährung auf *M. persicae* Imagines, festgestellt im Gewichtsunterschied (%) ihrer an verschiede nen Diäten saugenden Larven (6 Tage alte alatoide Morphen)

Diät	Gewichtsunterschied (%)			
	1. Tagslarven	2. Tagslarven	3. Tagslarven	4. Tagslarven
ohne Zusatz	100	100	100	100
mit ATP·Na_2	104	108	110	116
mit Na_2HPO_4	105	103	100	98

1. Tagslarven sind in den ersten 24 h auf der Diät geboren, usw. Eine dem Na-Gehalt der ATP-Diät äquimolare Na-Gabe hat keine signifikant unterschiedliche Wirkung zur Diät ohne Zusatz.

Frühjahr und Herbst, bisher nur im Zusammenhang mit dem Aminosäurespiegel diskutiert). Möglicherweise steht die ATP-Konzentration auch in einem bestimmten Zusammenhang mit der Höhe des Gehaltes an Zucker und Aminosäuren in der Diät. Alatoide Morphen erreichen schon bei geringen ATP-Gaben ein höheres Gewicht als apteroide, anderseits haben sie, an der ST-Diät saugend, weniger Kohlehydrate im Kot[10]. Vielleicht können sie Zucker schon bei geringerem ATP-Gehalt besser resorbieren.

Längere Zeit an der ST-Diät saugende Aphiden erscheinen verglichen mit natürlich ernährten Geschwistern als Kümmertiere. Dies kann mit einem ständig zunehmenden Mangel bestimmter Substanzen in der Diät gegenüber der Pflanze erklärt werden. Larven an der ATP-Diät (1,67 μM) werden mit zunehmendem Aufenthalt ihrer Mütter an dieser Diät schwerer als ST-Tiere und daher an der Pflanze saugenden Aphiden ähnlicher (Tabelle II).

ATP in der Diät kann mithin zu den Substanzen gezählt werden, die Mangelerscheinungen im Organismus der Mütter wie auch in der Embryonalentwicklung ihrer Larven verringern.

Die Ergebnisse zeigen, dass ATP für ein pflanzensaugendes Insekt wichtiger Bestandteil der künstlichen Diät ist. Auch unter natürlichen Verhältnissen an der Wirtspflanze dürfte ATP ein wichtiger Nahrungsfaktor sein und eine bedeutende Rolle in der Populationsdynamik der Art spielen. Welche physiologische Bedeutung ATP und möglicherweise weitere Komponenten des Adenylsäuresystems oder andere Nukleotide dabei haben, bleibt noch festzustellen.

Summary. Larvae and adults of the aphid *Myzus persicae* (Sulz.), reared on a synthetic diet, gain higher weight if their diet contains ATP (1.11 μM). The numbers of larvae born on diets with ATP are higher (20%) than on diets without ATP. The longer aphids were fed on the ATP-diet the more their weight increased compared with larvae on a diet without ATP. Generally ATP seems to balance the synthetic diet in whatever physiological way it may be. Since phloem sap contains a high level of ATP, it is suggested that ATP may also be of great importance under natural conditions on the host-plants.

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Tranexamic Acid and Fibrinolytic Activity of the Vessel Wall

The endothelium of certain vessels, especially veins, contain activators of fibrinolysis which are continuously liberated to the blood stream and maintain the spontaneous fibrinolytic activity of the blood. These activators serve to remove early fibrin deposits from the vessel walls and thereby to prevent thrombosis. The significance of the fibrinolytic activity in the vessel wall is apparent from the finding of a low activity in the vessel wall in 55% and/or an impaired release of activators to the blood in 73% of a series of patients with recurrent idiopathic thrombosis[1]. PANDOLFI et al.[2] found the fibrinolytic activity in the veins of the lower leg to be lower than that in the arms, a finding in accord with the higher frequency of thrombosis in the lower leg.

Tranexamic acid (AMCA) and epsilon-aminocaproic acid (EACA) are competitive inhibitors of plasminogen activation[3,4]. It would thus appear that, by virtue of their suppressive effect on the blood fibrinolytic activity, these inhibitors might invite thrombosis. But, as mentioned, it is the activator content by the vessel wall rather than that in the circulating blood which is of importance in preventing thrombosis.

In an endeavour to find out whether AMCA has an influence on the activator content of the vessel wall, the drug was given in large dosage to rats. The fibrinolytic activity in arteries and veins of the heart was estimated histochemically and compared with that in a control group.

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24 Sprague-Dawley male rats of uniform age and weighing 266 ± 15 g were used. 12 of the animals were given 2 g of AMCA in water solution per kg bodyweight a day in their drinking water for 8 weeks. The animals, which did not receive any other fluid, willingly drank the solution. 12 rats served as controls. At the end of this period, the rats were killed and the hearts immediately removed together with the large heart vessels. The specimens were immediately frozen in liquid nitrogen. Cryostat sections were placed in a plane through the large vessels (aorta, arteria and vena pulmonalis) immediately after their origin in the heart; others in a plane passing through the sulcus coronarius. The sections were cut 8 µm thick and collected on cleaned glass slides. 4 slides with 6 sections on each were prepared for every sample. The fibrinolytic activity was determined histochemically with the method of TODD[5], as modified and graded in arbitrary units by PANDOLFI[6].

The results are given in the Table. No significant differences were found between the rats treated with AMCA and the controls of the fibrinolytic activity in the walls of the large heart vessels or of the coronary vessels. These findings are compatible with observations in organ culture of veins in medium with an addition of AMCA. The activator content of these vessel explants did not differ from that of explants cultured without AMCA (ÅSTEDT, to be published).

Occurrence of microthrombi in the glomeruli[7–10] has been reported in some patients and a thrombotic state in one[11] during treatment with EACA. But in extensive clinical investigations, no increase in thrombotic complications has occurred during such traetment[12–15].

In the previous study, the potent fibrinolytic inhibitor AMCA was given in a large dose with no effect on the fibrinolytic activator content in the vessel wall. In agreement with the clinical experience, the results thus argue against AMCA, favouring the development of thrombosis.

Zusammenfassung. Ratten wurden mit hohen Dosen des Fibrinolyseinhibitors Tranexamsäure gefüttert. Die fibrinolytische Aktivität der grossen Herzgefässe und der Coronargefässe wurde histochemisch untersucht und mit einer Kontrollgruppe verglichen, wobei sich ergab, dass der Gehalt der Gefässwände an Fibrinolyseaktivatoren durch die Tranexamsäure nicht beeinflusst wurde.

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Fibrinolytic activity in the wall of the large heart vessels (aorta, art. and v. pulmonalis) and the coronary vessels of rats after treatment with AMCA 2 g/kg body weight a day for 2 weeks

Groups	Large heart vessels	Coronary vessels
AMCA	7.5 (6–8.5)	4.5 (2.0–6.0)
Controls	6.0 (3.0–9.5)	4.25 (3.0–7.0)

Arbitrary units. Median value and range.

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Ciliary Action and Normal Movement of Odorant Wavefronts in Garfish Nasal Capsule of *Lepisosteus osseus*

The olfactory receptors of most fish are distributed on lamellae within the nasal capsule. Odorants ordinarily reach the olfactory receptors of fish when streams of water enter the anterior nares and exit through the posterior nares. In fish, this flow is normally produced by various combinations of active and passive mechanisms[1].

Since movement of an odorant wave-front across the mucosa may be a relevant parameter of olfactory input[2], information concerning the normal movement of odorant wave fronts would be useful to those studying the physiology of olfactory stimulation. In fish, flow patterns in the nasal capsule have been studied only in the eel[3].

The present report shows the relationship in the capsule between flow patterns and distribution of receptors on the lamellae of the garfish, *Lepisosteus osseus*. We suggest that ciliary currents are responsible for the efficient delivery of odorant molecules to the olfactory receptors, and prevent the existence of an unstirred layer along the epithelium.

Figure 1 illustrates the left nasal capsule after the dorsolateral wall has been removed. The lamellae are attached to the capsule along their medial and ventral borders. The nasal capsule of the garfish has no ancillary pumping structures such as are present in most teleosts[1], and flow is produced by action of cilia. In a 0.75 m fish, the capsular volume (determined by a paraffin-casting procedure) was 0.04 cm³, while that of a 1 m fish was 0.065 cm³. These volumes may be over-estimates because of tissue shrinkage caused by fixation and treatment with hot paraffin.

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