Projeto de Lei n° 3441, de 2021
Dia do Físico e do Biofísico

Prof. Dr. Vagner R. Antunes

Chefe de Departamento

Departamento de FISIOLOGIA E BIOFÍSICA

ICB USP

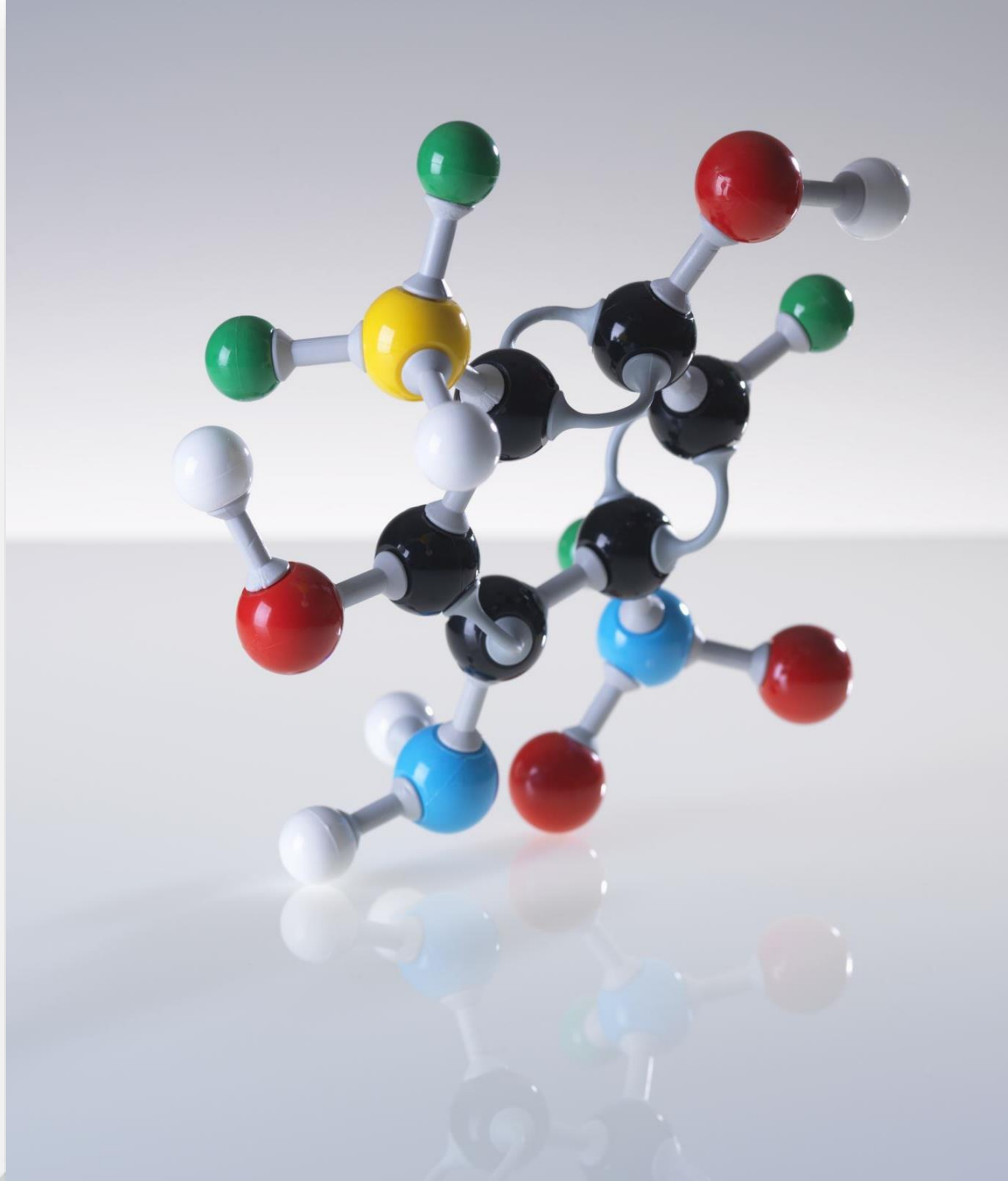
BIOFÍSICA

- Corresponde a aplicações de conceitos científicos físicos à compreensão dos mecanismos que propiciam a vida;

- O estudo da biofísica teve início no século XIX, quando os princípios da física estabelecidos por Isaac Newton começaram a ser aplicados nas ciências biológicas.

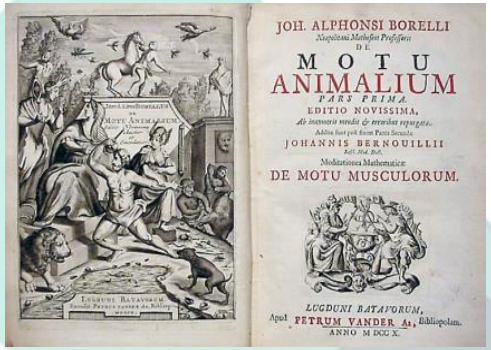
- Estudo em escala macro e microscópica dos fenômenos físico-biológicos que envolvem organismos vivos, e em escala molecular; os comportamentos resultantes de vários processos da vida, além da interação e da cooperação entre os sistemas altamente organizados de macromoléculas, organelas e células;

- É possível dizer que nenhum estudante das ciências da vida de hoje será adequadamente educado/formado sem uma firme compreensão dos princípios fundamentais da ciência física, que são objetivos deste curso.

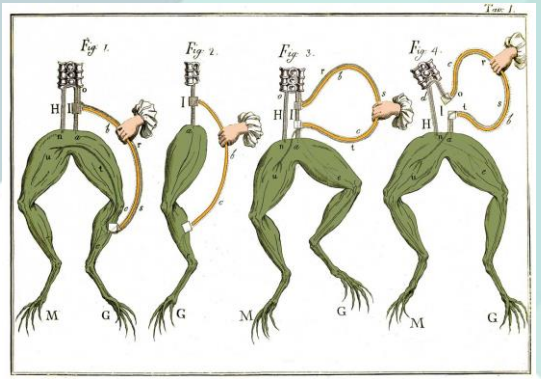


Aplicação da física na biologia ao longo da história

- **Giovanni Alfonso Borelli (1608-1679)**
  - *Pai da biomecânica*
  - *Primeiro a propôr que os músculos não exercem um movimento vital, mas sim de contração*



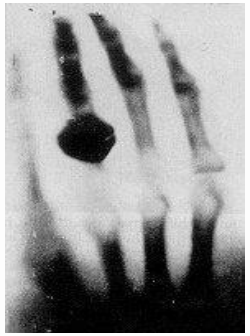
- **Luigi Galvani (1737-1798)**
  - *Médico, físico e filósofo que, estudando coxas de rãs, descobriu que músculos e células nervosas eram capazes de produzir eletricidade – BIOELETRICIDADE!*



“Eu não achei, eu pesquisei!”

- **Wilhelm Conrad Roentgen (1845-1923)**
  - *Físico que descobriu os raios-X em 8 de novembro de 1895*
  - *Em 1901, recebeu o Premio Nobel de Física pela descoberta dos raios-X*

- Primeira radiografia da história, a mão de sua esposa, Dona Bertha,



Godfrey N. Hounsfield

Allan M. Cormack

- **Godfrey N. Hounsfield (1919-2004)** – Engenheiro elétrico britânico
- **Allan McLeod Comarck** – Físico sul-africano

  - *Prêmio Nobel em Fisiologia e Medicina em 1979 pelo desenvolvimento da tomografia computadorizada (TC)*

Uma breve história...

ICB USP

Departamento de
FISIOLOGIA
E BIOFÍSICA

UNIVERSIDADE DE SÃO PAULO
Instituto de Ciências Biomédicas

Os primórdios da fisiologia e biofísica em São Paulo

- No início do século XX, a Faculdade de Medicina de São Paulo buscou na Europa os primeiros mestres para suas cadeiras básicas.

- Inicialmente, a cadeira de Fisiologia contou com a orientação de Lambert Meyer, que trouxe para São Paulo a experiência da escola fisiológica francesa.

- As cadeiras de Fisiologia e Farmacologia foram o núcleo inicial do Departamento de Fisiologia e Biofísica do Instituto de Ciências Biomédicas (ICB) da Universidade de São Paulo (USP).

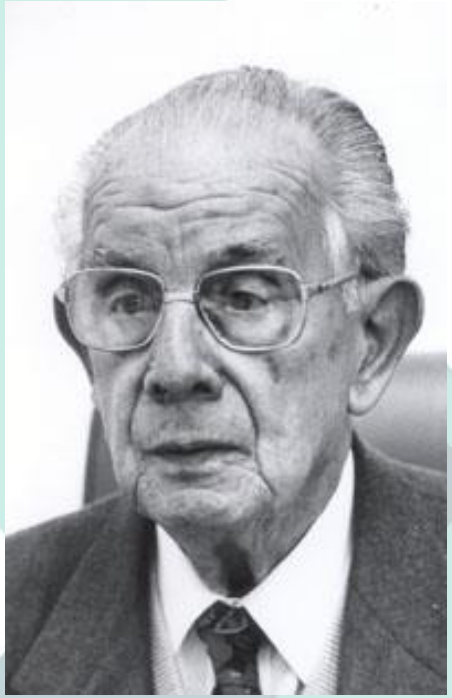
Entretanto, a pesquisa em Fisiologia se iniciou quando o Professor Cantídio de Moura Campos assumiu a cátedra.

Prof. Cantídio de Moura Campos (1889-1972)

- Dentro desta linha de pesquisa, destaca-se também o Prof. Alberto Carvalho da Silva, catedrático da Faculdade de Medicina da USP;

- O Prof. Alberto foi um eminente fisiologista que reformulou o ensino prático de Fisiologia;

- Foi professor emérito da USP, presidente de honra da Sociedade Brasileira para o Progresso da Ciência (SBPC) e fundador, Diretor Científico e Presidente da FAPESP, tendo ocupado importantes postos no Instituto de Estudos Avançados da USP e na Organização Mundial da Saúde.



Prof. Alberto Carvalho da Silva (1916-2002)

- Em 1968, com a Reforma Universitária, as Cátedras foram transformadas em Departamentos, cada um administrado por um Conselho Departamental e 1969 surge o ICB.

- Os docentes que se dedicavam à Fisiologia e à Farmacologia nas diferentes Unidades da USP ligadas à Saúde – Faculdades de: Medicina, Odontologia, Medicina Veterinária e Farmácia e Escola de Educação Física – foram integrados ao Departamento de Fisiologia e Farmacologia do ICB.

Em 1982, com a separação da Farmacologia, houve a criação do Departamento de Fisiologia e Biofísica do ICB

Departamento de FISIOLOGIA E BIOFÍSICA

Renomados fisiologistas e biofísicos egressos do Departamento de Fisiologia e Biofísica da USP:

Antônio Carlos Bianco, Cesar Timo-Iaria (1924-2005), Francisco Gacek, Francisco Lacaz Vieira, Gerhard Malnic, Irineu T. Velasco, Joaquim Procópio de A. Filho, Juarez Aranha Ricardo (1946-1991), Lor Cury (1935-2002), Luiz Menna-Barreto, Luiz Eduardo Ribeiro do Valle, Maurício da Rocha e Silva Jr., Margarida de Mello Aires (1935-2019), Massako Kadekaro, Miguel Nassif, Nancy Amaral Rebouças, Naomi Shinomiya Hell, Newton Canteras, Núbio Negrão (2015), Oswaldo Ubríaco Lopes, Pedro Guertzenstein (1938-1994), Rebeca Carlota de Angelis (1925-2007), Ronald D. P. K. Clive Ranvaud, Rui Curi, Sara J. Shammah-Lagnado, Sérgio Cravo, Sonia Malheiros Lopes Sanioto, Thomas Maack.

Prof. Gerhard Malnic
1933 - 2023

- Nasceu em Milão, em 26/09 de 1933;
- Filho de austríacos: nacionalidade austríaca
- Mudou-se para o Brasil com 4 anos de idade;
- Naturalizou-se brasileiro aos 23 anos (1956)
- Médico, pela Faculdade de Medicina da USP, obteve o título de Doutor, 1960 e de Livre-Docente em Fisiologia, em 1965.
- Em 1973, tornou-se Titular do Departamento de Fisiologia e Farmacologia do ICB/USP.
- Diretor do ICB/USP e do Instituto de Estudos Avançados – IEA/USP; Presidente das Sociedades Brasileira de Biofísica (1983-1985) e de Fisiologia (1985-1988);

MEMBRO TITULAR:

- Academia Brasileira de Ciências,
- Academia de Ciências do Estado de São Paulo
- Academia de Ciências da América Latina

HONRARIAS:

- Comendador da Ordem Nacional do Mérito Científico - Presidência da República do Brasil – em junho de 1995
- Grã-Cruz da Ordem Nacional do Mérito Científico - Presidência da República do Brasil – em agosto de 2000
- Medalha G.A. Borelli, Universidade Frederico II, Napole, Itália
- Medalha CAPES 50 Anos - CAPES/MEC – em julho de 2001

- Prof. Malnic concluiu o seu doutorado em Fisiologia, sob orientação do Professor Alberto Carvalho da Silva, em 1960

UNIVERSIDADE DE SÃO PAULO
Instituto de Ciências Biomédicas

GERHARD MALNIC

à Rebeca
com um abraço do
Malnic.

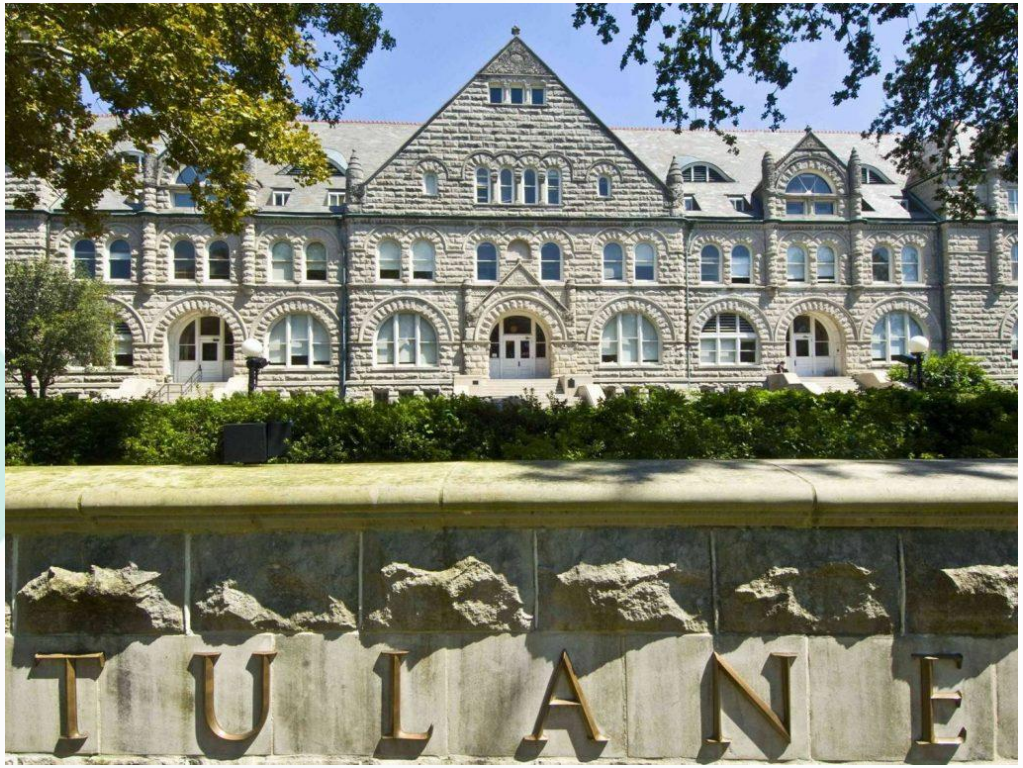
CONTRIBUIÇÃO AO ESTUDO DO MECANISMO DA EXCREÇÃO RENAL DE TIAMINA NO CÃO.

Tese de Doutoramento em Fisiologia apresentada à Faculdade de Medicina da Universidade de São Paulo.

1959

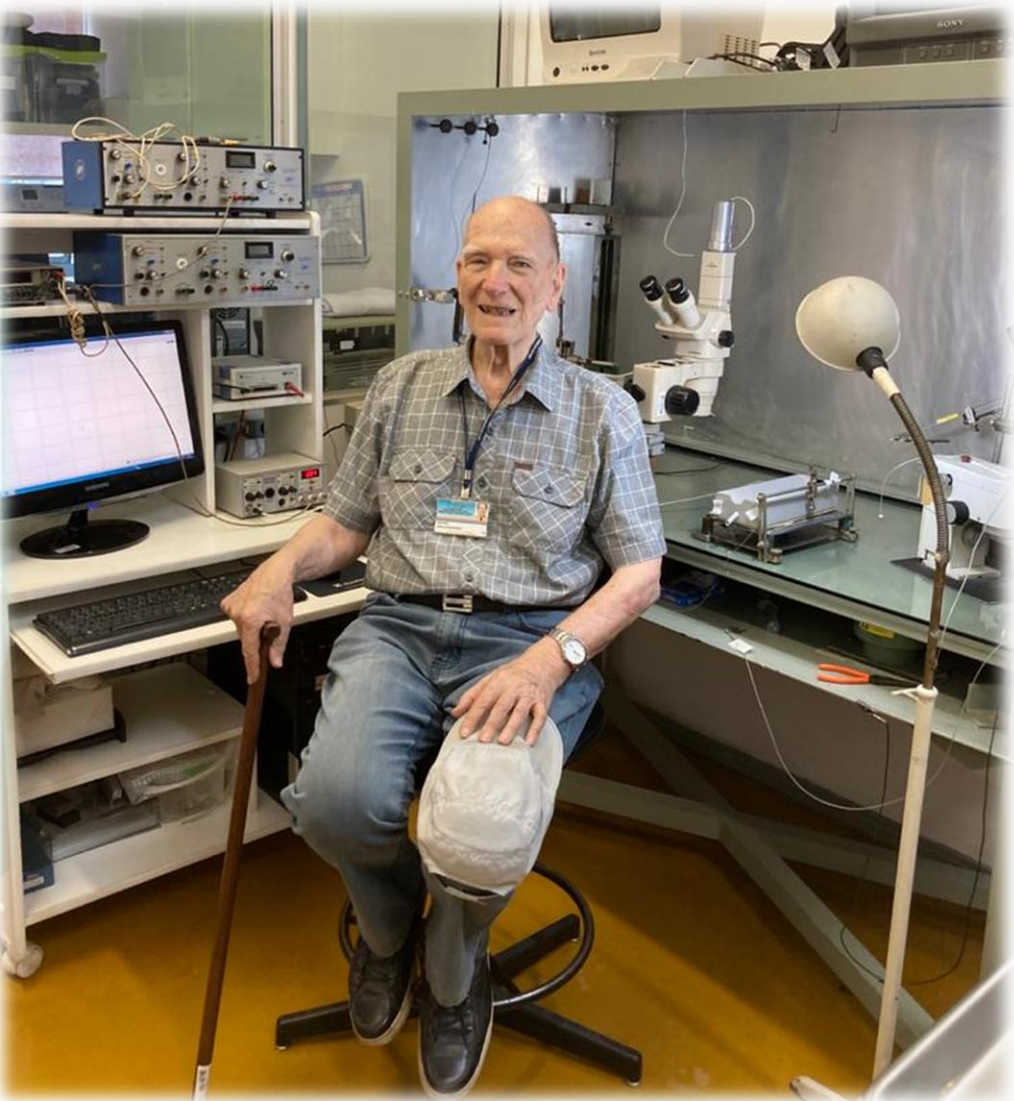
PÓS-DOUTORADO

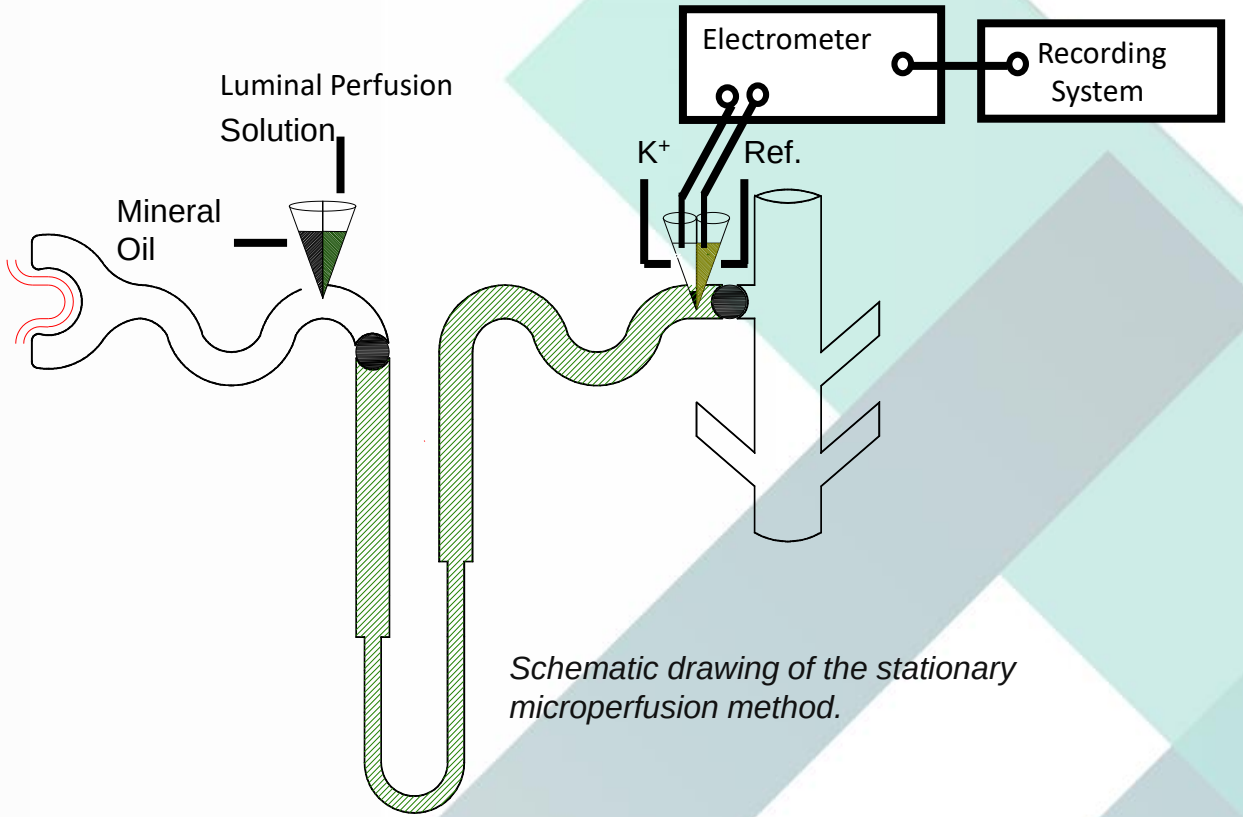
- *Tulane University*, Nova Orleans, entre 1961 e 1962;
- *Cornell University Medical College*, Nova York, entre 1962 e 1964




Cornell Medical College

- De volta à USP, em 1964, implantou o laboratório de micropunção e microperfusão renal na Faculdade de Medicina da USP;
- Métodos experimentais inexistentes no Brasil na época.





Schematic drawing of the stationary microperfusion method.

Os estudos do professor Malnic contribuíram significativamente para o avanço da fisiologia e biofísica renal no Brasil e no mundo.

J Am Soc Nephrol 11: 1354–1369, 2000

Micropuncture study of renal potassium excretion in the rat[1,2]

GERHARD MALNIC,[3] RUTH M. KLOSE, AND GERHARD GIEBISCH[4]

Department of Physiology, Cornell University Medical College, New York City

with comments by

GERHARD GIEBISCH AND DONALD W. SELDIN

Reprinted from Am. J. Physiol. 206: 674–686, 1964

MALNIC, GERHARD, RUTH M. KLOSE, AND GERHARD GIEBISCH. *Micropuncture study of renal potassium excretion in the rat.* Am. J. Physiol. 206(4): 674–686, 1964.–Samples of proximal and distal tubular fluid were collected from rats maintained on a control, a low-K, or a high-K, low-Na diet. All animals received inulin-C^{14}. Plasma (P) and tubular fluid (TF) were analyzed for Na and K by dual-channel microflame photometry and assayed for radioactivity. Transtubular electrical potential differences were measured by means of glass microelectrodes. Mean TF/P ratios for potassium in the proximal tubule were slightly below unity in all groups of animals. A comparison of the relative increase in K and inulin-C^{14} along the distal tubule indicates: 1) net movement of potassium into the tubular lumen in most control animals; 2) net movement of K into the tubular lumen of high-K, low-Na, sulfate-loaded animals, and in dichlorphenamide-treated animals on a control diet; and 3) the possibility of continued net reabsorption of potassium along the distal tubule and, particularly, the collecting duct in animals kept on a low-K diet. Distal tubular entry of potassium occurs down an electrochemical potential gradient.

tubular potassium secretion tubular potassium reabsorption potassium transfer

THE CONTRIBUTION of the various tubular segments to the process of potassium excretion in different metabolic situations is not well defined. The fact that potassium clearances can significantly exceed glomerular filtration rate in a variety of species demonstrates that the kidney has a tubular mechanism for the secretion[5] of potassium ions (3). Evidence for a distal tubular site of potassium secretion has also become available by the use of stop-flow techniques (1, 16, 28, 34, 40, 41), and by catheterization of individual collection ducts (14). On the basis of clearance experiments, Berliner et al. (3) have suggested that even under the normal condition of extensive net reabsorption, urinary potassium is derived from distal tubular secretion, implying that tubular reabsorption is virtually complete in the proximal tubular system. This view is based, essentially on the demonstration that potassium excretion can be independent of the filtered amount of this ion.

The situation is somewhat complicated by other experimental results, which indicate that the distal nephron may also be the site of significant net reabsorption. In particular, a number of observations obtained by stop-flow techniques suggest such a possibility (1, 34, 40), and it has also been shown that the potassium concentration in the final urine may fall below that of plasma (19). Such observations raise the possibility that the distal tubular pattern of potassium transfer may vary, and that the direction of net movement of potassium may change as a function of the metabolic situation and of other intrarenal factors.

Available data from micropuncture studies in general support the thesis of extensive proximal tubular potassium reabsorption in the mammalian nephron (6, 17, 21, 22, 42). However, little direct information on the behavior of more distal parts of the nephron is available. Thus, the present study was undertaken to assess the extent and site of tubular reabsorption and of the net transfer of potassium into the tubular lumen during widely differing excretion patterns. These included variations in dietary potassium intake, the administration of a carbonic anhydrase inhibitor, and a number of techniques known to stimulate potassium secretion. In addition, electrical potential differences were measured across various tubular segments to gain information concerning transtubular potassium movement with respect to the corresponding electrochemical potential gradient.

METHODS

General procedure. Male albino rats weighing 300–400 g were anesthetized by intraperitoneal injection of pentobarbital (30–40 mg/kg body wt.). The animals had free access to water and food until the time of the experiment. Four groups of rats were used. The first group was maintained on a control diet (Purina lab chow, 0.72% K, 0.46% Na). A second group was kept on a commercial low potassium diet (Nutritional Biochemicals Corp., Cleveland 28, Ohio. Composition: cornstarch, 64.2%, casein, 30%, butterfat, 3–5%, calcium carbonate, 1.3%, sodium chloride, 1%, plus vitamin supplement) for at least 3 weeks prior to the experiment. During the experiment both of these groups

Received for publication 17 July 1964.

AUTHOR COMMENTARY

Gerhard Giebisch

Department of Cellular and Molecular Physiology, Yale University School of Medicine
New Haven, Connecticut

I joined the Department of Physiology at Cornell Medical College in the early 1950s and spent several years working on problems of renal electrolyte and fluid transport in dog kidneys before becoming interested in renal micropuncture. At that time, studies of renal function were mostly based on clearance methods in whole animals. The interpretations of clearance data with regard to localization of specific transport processes and mechanisms, especially with respect to the mammalian kidney, depended heavily on very few direct studies of single nephron function. The renal transport of potassium attracted my attention because of the ongoing work in the Department of Physiology at Cornell that had focused on the relation between hydrogen and potassium transport. Also, the papers of Berliner, Kennedy, and Orloff suggested, on the basis of ingenious clearance experiments, that potassium excretion depended on the complex interaction between extensive reabsorption in the proximal nephron and regulated secretion in distal nephron segments (1,2). Why not test these intriguing clearance-based interpretations by collecting fluid and following the events of potassium

Gerhard Malnic, 1965.

Ruth M. Klose, 1962.

Gerhard Giebisch, 1962.

the amphibian proximal tubule. At the time of my stay in her laboratory, Dr. Bott spent a large amount of time attempting to develop a refined flame photometer that would make possible measurements of sodium and potassium in nanoliter samples of tubule fluid, but never fully succeeded (4).

When I returned to Cornell, I first carried out some electrophysiologic studies on the *Necturus* kidney. I was soon joined by Erich Windhager from A. K. Solomon's laboratory, and we decided to switch to the mammalian tubule. Carl Gottschalk at Chapel Hill had already shown the feasibility of such studies in his early measurements of the hydrostatic pressure in tubules, and we were encouraged to try fluid collection from rat tubules. Our first mammalian micropuncture study dealt with the demonstration of active sodium reabsorption in the proximal tubule, but what had started as a promising beginning in the puncture of mammalian tubules was unexpectedly interrupted because Erich Windhager's visa required that he leave the United States for at least 2 years. He spent those 2 years profitably in the laboratory of Hans Ussing in Copenhagen. I was very fortunate, however, to be joined at that time by Gerhard Malnic from Sao Paulo, and Ruth Klose, who had previously joined our laboratory as a research associate. I could not have asked for better coworkers. Gerhard Malnic was not only talented and creative but extremely hard-working and a pleasure to collaborate with. I might mention that after his return to South America, he played a major role in developing renal physiology in his home country of Brazil. Another important link was Ruth Klose, who had already mastered micropuncture before Gerhard Malnic's arrival in New York. Her level of expertise was excellent, and her creative input was integral to our efforts. We all have remained good friends since the days of our happy collaboration at Cornell.

We decided to tackle the potassium problem and "return" to sodium after Erich Windhager's return from Europe. It became apparent that we needed a sensitive, reliable, and affordable method for measuring potassium and sodium in samples of tubule fluid. Although the use of radioactive sodium and fine-tuning the available "macro" flame photometers were possibilities for measuring ions in small fluid samples, both had problems with accuracy and reproducibility. It was indeed a real stroke of luck that as I was brows-

Trabalho Científico com destaque

PHYSIOLOGY

Effect of 'Furosemid' on Chloride and Water Excretion in Single Nephrons of the Kidney of the Rat

It has been shown by Muschaweck and Hajdú[1] that in the dog, at doses of 10 mg/kg body-wt. and more, 'Furosemid' (4-chloro-*N*(2-furylmethyl)-5-sulphamoyl-anthranylic acid) markedly increases the excretion of water, sodium and chloride. These authors also showed that the increase in chloride excretion was proportionally greater than that of sodium and water. On the other hand, Karger and Nagel[2] found a reduced permeability to anions, especially chloride, in the frog skin after addition of 'Furosemid' at concentrations of 25–500 mg/l. to the bathing solution, as evidenced by increased transmembrane potential differences without change in the short circuit current. Deetjen[3] obtained proximal and distal tubular fluid samples in rats with an intravenous infusion of 2 mg/kg/min and observed significantly decreased proximal fluid/plasma (F/P) inulin ratios, as well as ratios below 2 in the distal tubule, concluding that 'Furosemid' depresses water and salt re-absorption in the proximal tubule and ascending limb of Henle's loop. Clearance studies by Suki, Rector and Seldin[4] also indicated that 'Furosemid' might have an effect on the activity of the re-absorptive mechanisms of the proximal tubule and the ascending limb of Henle's loop.

Having this evidence in mind, we decided to investigate the fate of chloride along the nephron of the rat kidney, using micropuncture methods as described by Windhager and Giebisch[5]. Extreme care was taken in the collection of distal tubular samples, using rather long oil blocks (at least four times the tubular diameter), and checking the direction of flow by subsequent microdissection. Chloride and inulin were measured simultaneously, the first by the second coulometric method of Ramsay *et al.*[6], the second by a modification of the microanthrone method of Hilger *et al.*[7]. 'Furosemid' was infused in saline (0·05 ml./min) at a rate of 0·8 to 1 mg/kg/min, sufficient to produce a marked diuresis. In parallel experiments the same measurements were done in control rats receiving saline infusion (0·05 ml./min) and in animals receiving a 4 per cent sodium chloride infusion at a rate of 0·1 ml./min.

Mean glomerular filtration rate (GFR) was 3·21 ml./kg/min in the 'Furosemid' group, 4·22 in the control group, and 5·77 in the 4 per cent sodium chloride group. Mean urinary *p*H was 6·32 (range 5·95–6·71) in the control group, 6·50 (5·99–6·83) in the 4 per cent sodium chloride infused, and 5·26 (4·76–5·82) in the 'Furosemid' group.

In Table 1*a* mean chloride F/P ratios in proximal and distal tubules, as well as chloride U/P ratios, are shown

Table 1

(a) Chloride F/P ratios*

	Proximal			Distal			Urine		
	Mean	Range	No.	Mean	Range	No.	Mean	Range	No.
Control	1·29	1·07–1·43	(12)	0·30	0·12–0·56	(15)	0·29	0·05–1·16	(11)
NaCl 4%	1·24	1·15–1·41	(8)	0·46	0·25–0·78	(10)	2·34	2·01–2·80	(7)
'Furosemid'	1·29	1·20–1·41	(10)	1·27	1·13–1·47	(15)	1·45	1·36–1·65	(15)

(b) Inulin F/P ratios

	Proximal			First 1/2 distal			Urine		
	Mean	Range	No.	Mean	Range	No.	Mean	Range	No.
Control	2·08	1·15–3·78	(11)	6·01	3·73–7·80	(10)	201·2	56–356	(12)
NaCl 4%	1·39	1·04–1·85	(8)	2·28	1·87–3·28	(9)	17·5	8·8–32·4	(7)
'Furosemid'	1·75	1·21–2·51	(7)	4·51	2·97–5·92	(9)	7·6	5·2–10·7	(15)

* Not corrected for an experimental ultrafiltrate/plasma ratio of 1·06.

in the 'Furosemid' and in the control groups. It can be seen that all three groups show similar proximal ratios, above unity. In the distal tubule, however, there is a marked difference between the control groups, having ratios significantly below unity, and the 'Furosemid' group, showing ratios consistently above one, similar to those observed in proximal tubules. There is a considerable rise in chloride ratios between distal tubules and collecting duct urine in the group receiving 4 per cent sodium chloride, but only very little further increase in the 'Furosemid' group. In Table 1*b* the corresponding inulin concentration ratios are seen. The proximal tubular inulin ratios are somewhat reduced, though not so much as those in the experiments of Deetjen[3], probably due to our lower rate of infusion of 'Furosemid'. A larger reduction is observed in the early distal samples. On the other hand, it is noteworthy that there is little difference between the distal and urine inulin ratios in the 'Furosemid' group, as compared with the 4 per cent sodium chloride infused rats. The inulin ratios obtained in the latter group are similar to those obtained by Giebisch *et al.*[8]. Electrical potential difference measurements with glass microelectrodes in the 'Furosemid' infused rats showed proximal and distal transtubular potential differences within the range of controls (means −19·0 and −50·6 mV, respectively).

The results obtained in these experiments show that the mechanism of diuresis in rats undergoing 4 per cent sodium chloride infusion and during 'Furosemid' infusion is a quite different one, in spite of roughly similar overall chloride excretion rates (mean urinary Cl/inulin excretion rates of 0·13 in sodium chloride infused, and 0·19 in 'Furosemid' infused rats).

It appears that at our infusion rates of 'Furosemid' there is a relatively small inhibition of proximal and distal tubular fluid re-absorption. The major effect observed appears to be an impairment of the re-absorption of sodium chloride in excess of water in the ascending limb of Henle's loop, a process which constitutes the 'single effect' for the counter-current multiplier system of the renal medulla[9]. As shown by the high early distal chloride ratios in the 'Furosemid' group, the normally occurring hypotonicity of the tubular fluid at this site is absent, a further indication of impairment of the transport mechanisms in the ascending limb of Henle's loop. From our results, it appears that, due to inhibition of chloride and fluid re-absorption at this site, the build-up of a medullary salt concentration gradient might be impaired, as evidenced by the reduced further increase in the chloride and inulin F/P ratios between distal tubule and final urine. These experiments suggest, therefore, that 'Furosemid' in doses of 0·8–1 mg/kg body-wt./min acts preferentially on the sodium chloride transport system of the ascending limb of Henle's loop and the early distal convolution, preventing the establishment of a considerable concentration gradient for sodium chloride along these tubular segments.

This work was supported by a grant from Fund. de Amparo à Pesquisa do E. S. P. We thank Dr. Phyllis Bott and Dr. Gerhard Giebisch for the loan of equipment and for their advice. We also thank Dr. Wilhelm Fill, from Hoechst do Brasil, for the supply of 'Furosemid'.

Gerhard Malnic
Francisco Lacaz Vieira
Hiroko Enokibara

Department of Physiology,
University of São Paulo,
Brazil.

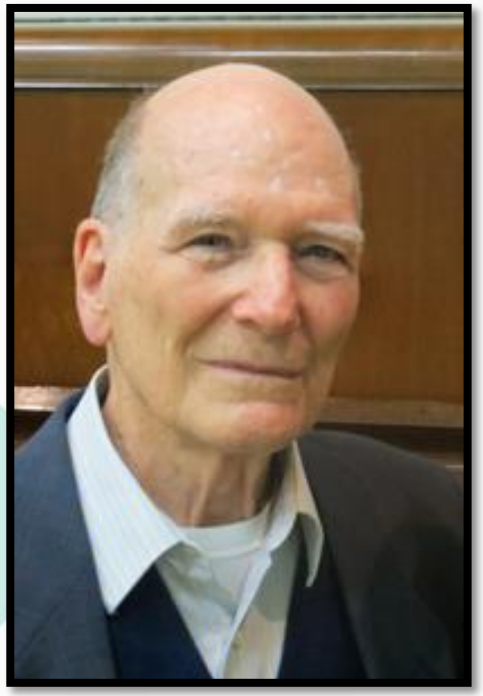
[1] Muschaweck, R., and Hajdú, P., *Arzneimittel-Forschung*, **14**, 44 (1964).
[2] Karger, W., and Nagel, W., lecture, Twenty-ninth Meeting of German Physiol. Soc., Bad Nauheim (1964).
[3] Deetjen, P., Symp. on Lasix, Bad Homburg (1963).
[4] Suki, W., Rector, F. C., and Seldin, D. W., *Clin. Res.*, **12**, 260 (1964).
[5] Windhager, E. E., and Giebisch, G., *Amer. J. Physiol.*, **200**, 581 (1961).
[6] Ramsay, J. A., Brown, R. H. J., and Croghan, P. C., *J. Exp. Biol.*, **32**, 822 (1955).
[7] Hilger, H. H., Kluemper, J. D., and Ullrich, K. J., *Arch. Ges. Physiol.*, **267**, 218 (1958).
[8] Giebisch, G., Klose, R. M., and Windhager, E. E., *Amer. J. Physiol.*, **206**, 687 (1964).
[9] Ullrich, K. J., *Prog. Cardiovasc. Dis.*, **3**, 395 (1961).

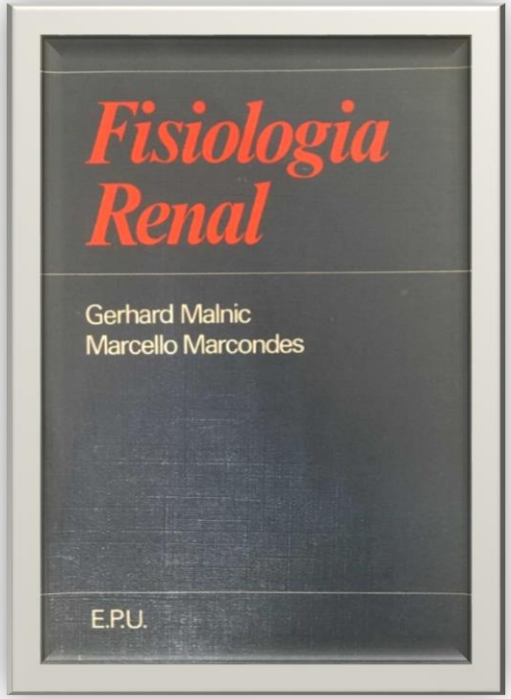
Malnic G., Vieira F.L, Enokiara H.

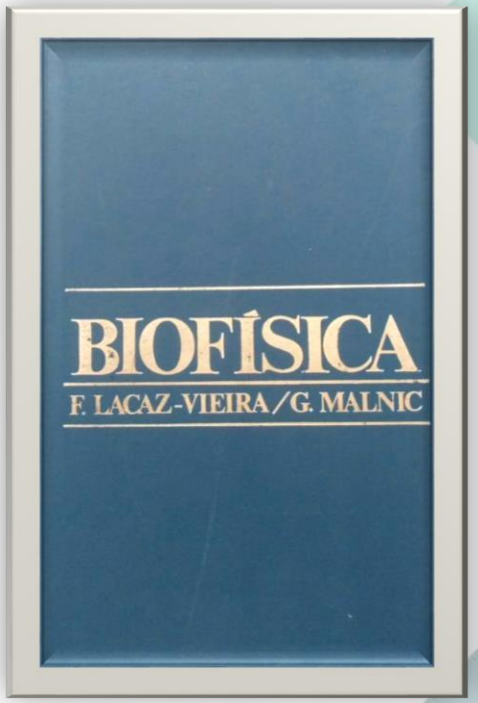
Effect of Furosemid on chloride and water excretion in single nephrons of the kidney of the rat.

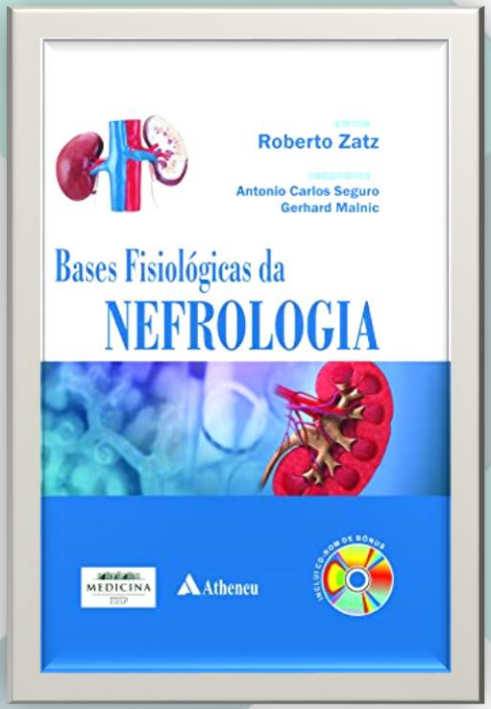
Nature (London), v. 208, p. 80-81, 1965.

O conhecimento imortalizado em livros!





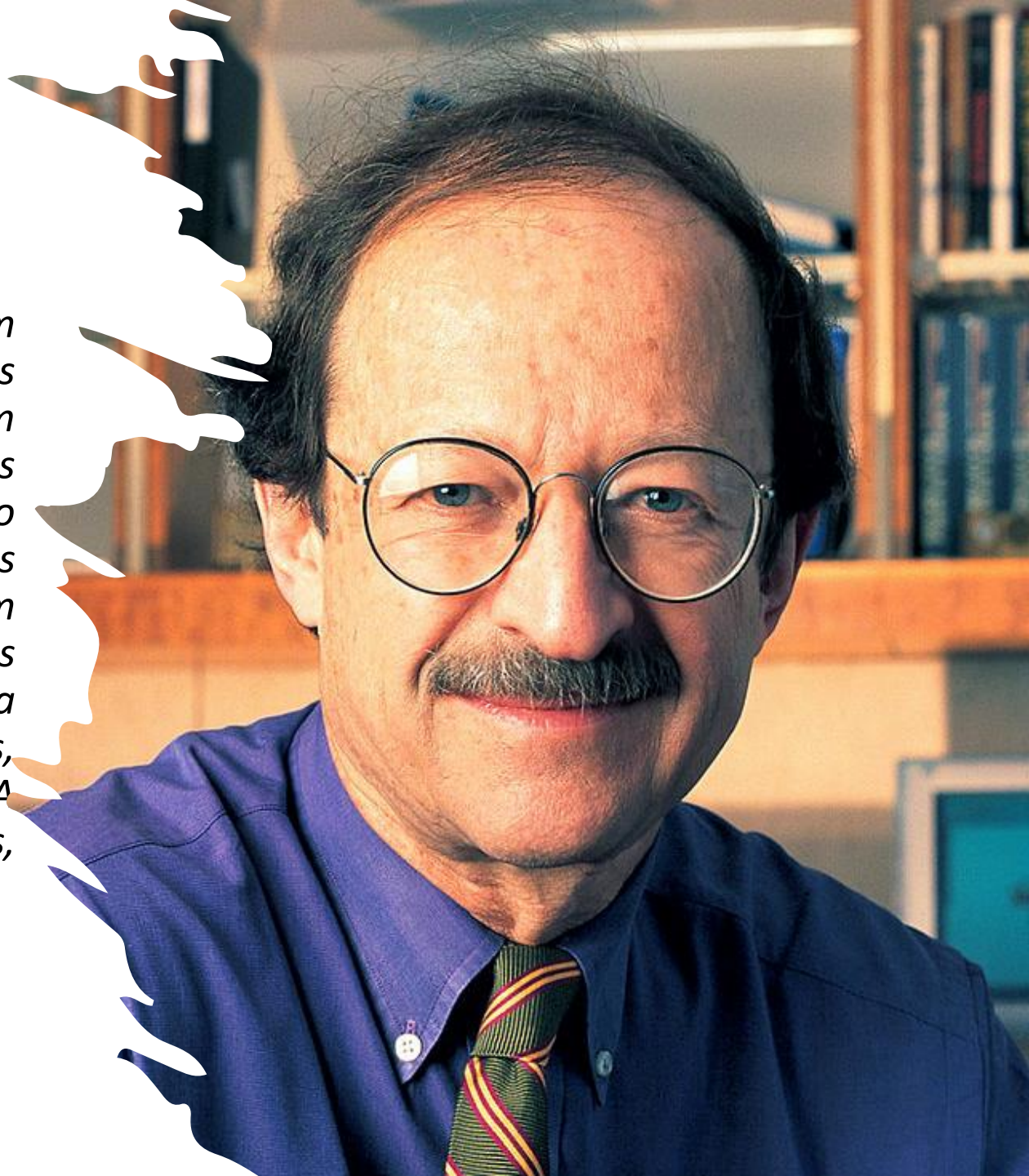




Harold Varmus

Prêmio Nobel de Fisiologia e Medicina, 1989

"A maioria das mudanças revolucionárias que ocorreram na biologia e na medicina estão calcadas em novos métodos. E esses, usualmente, estão calcados em descobertas fundamentais em outras áreas. Algumas delas são tão óbvias que nem as percebemos – como o papel da física nuclear na produção de radioisótopos essenciais para a medicina moderna. A física também forneceu os ingredientes fundamentais para muitas aplicações clínicas comuns – raios-X, tomografia computadorizada, vídeo-endoscopia por fibras óticas, cirurgia a laser, ecocardiografia, e ultrassonografia. A ciência dos materiais está contribuindo com novas juntas, válvulas cardíacas e outros substitutos para tecidos."



Continua...

American Association for the Advancement of Science – AAAS
Conferência Plenária, 13/02/1998)

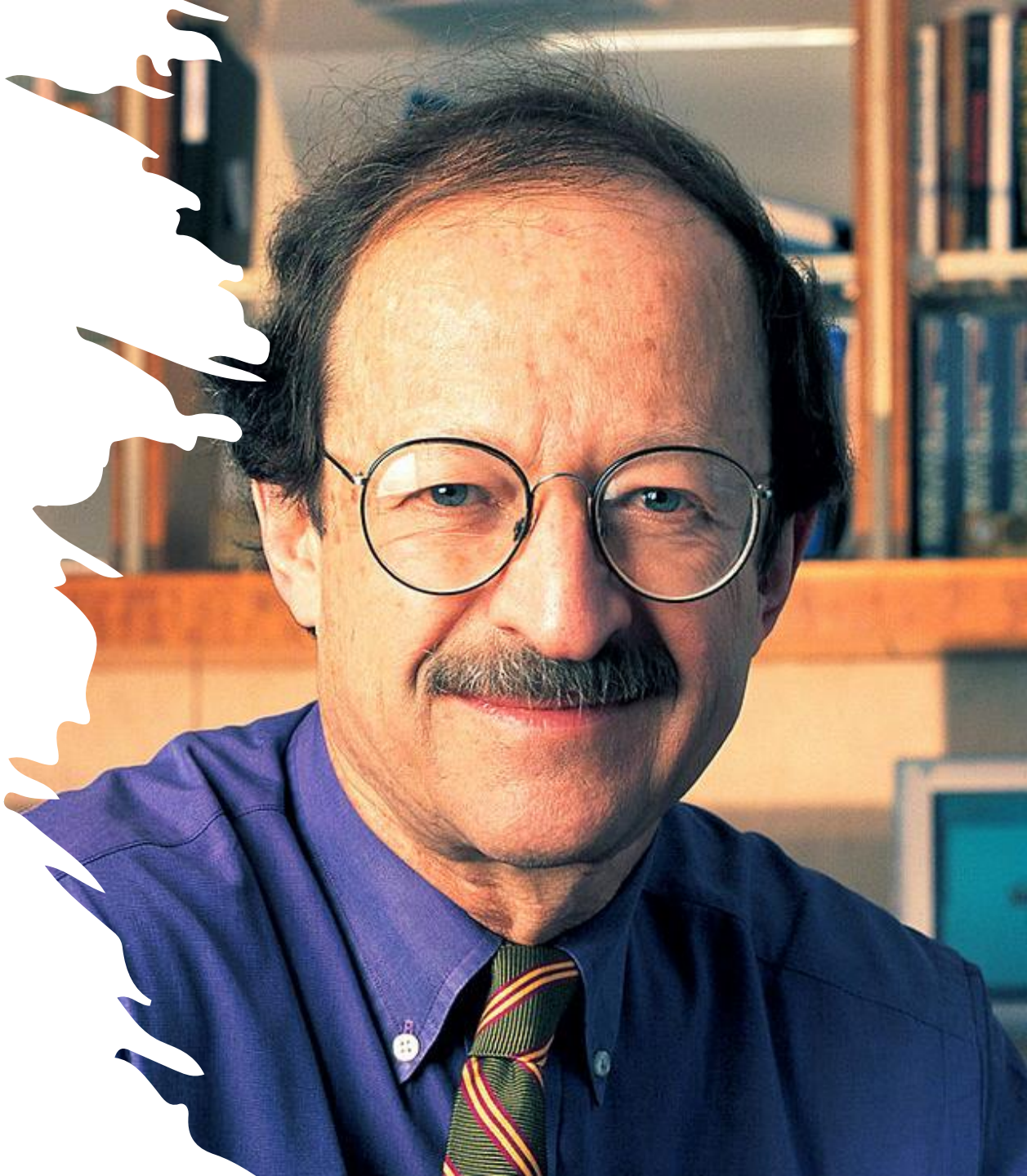
Harold Varmus

Prêmio Nobel de Fisiologia e Medicina, 1989

"Igualmente, um entendimento da ressonância magnética nuclear e das emissões de pósitrons foi necessário para os experimentos com imagens que nos permitem localizar e cronometrar as atividades cerebrais que acompanham pensamentos, movimentos, e sensações.

Da mesma forma, a cristalografia por raios-X, a química e a modelagem computacional estão agora sendo usadas para melhorar o "design" de fármacos, baseado na determinação da estrutura tridimensional de proteínas…

Esses são apenas poucos de muitos exemplos da dependência das ciências biomédicas de uma vasta gama de outras disciplinas, tais como a física, a química, a engenharia e muitos outros campos aliados."



Obrigado pela atenção!

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