



Escola Politécnica da Universidade de São Paulo

SISTEMA CARDIO-RESPIRATÓRIO

HENRIQUE TAKACHI MORIYA



Escola Politécnica da Universidade de São Paulo

SISTEMA CARDIO-RESPIRATÓRIO: FISIOLOGIA DO SISTEMA RESPIRATÓRIO

HENRIQUE TAKACHI MORIYA

LEB
EPUSP

PLEURAS

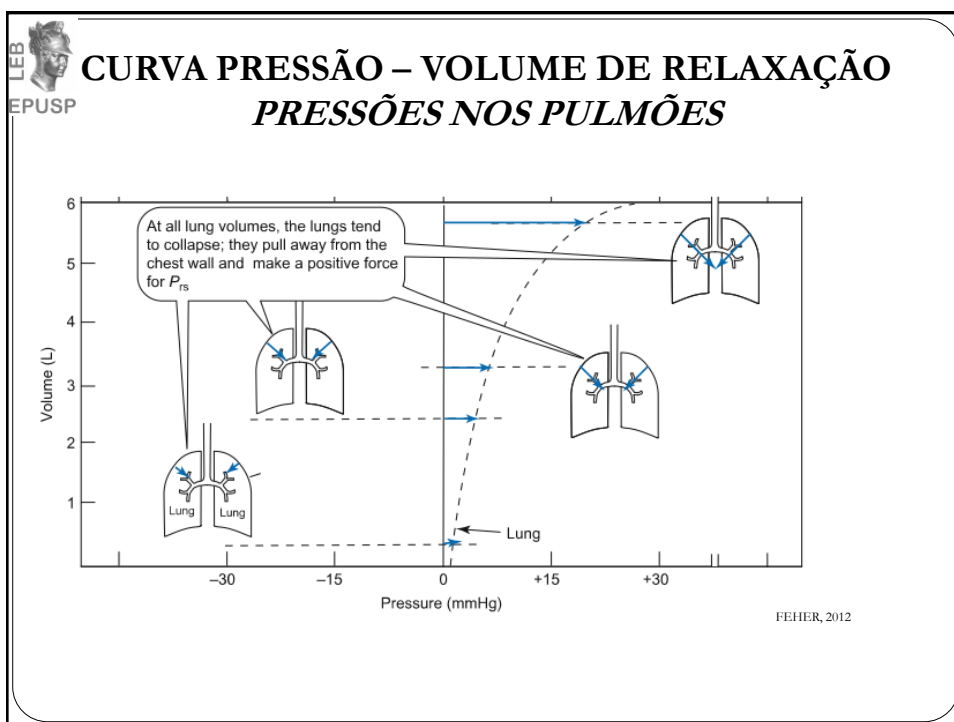
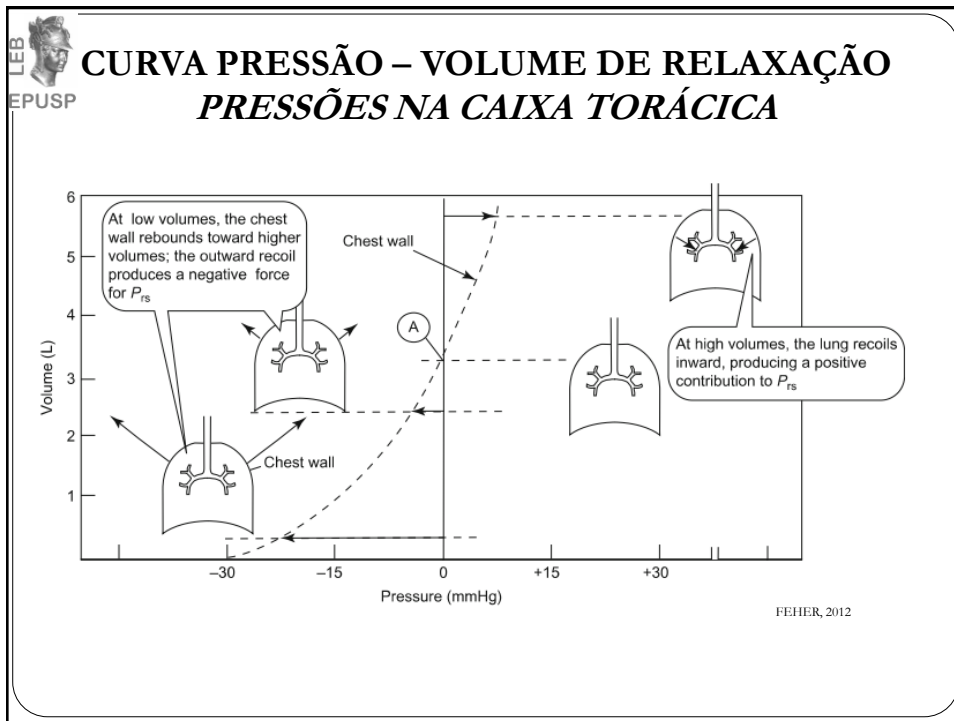
FEHER, 2012

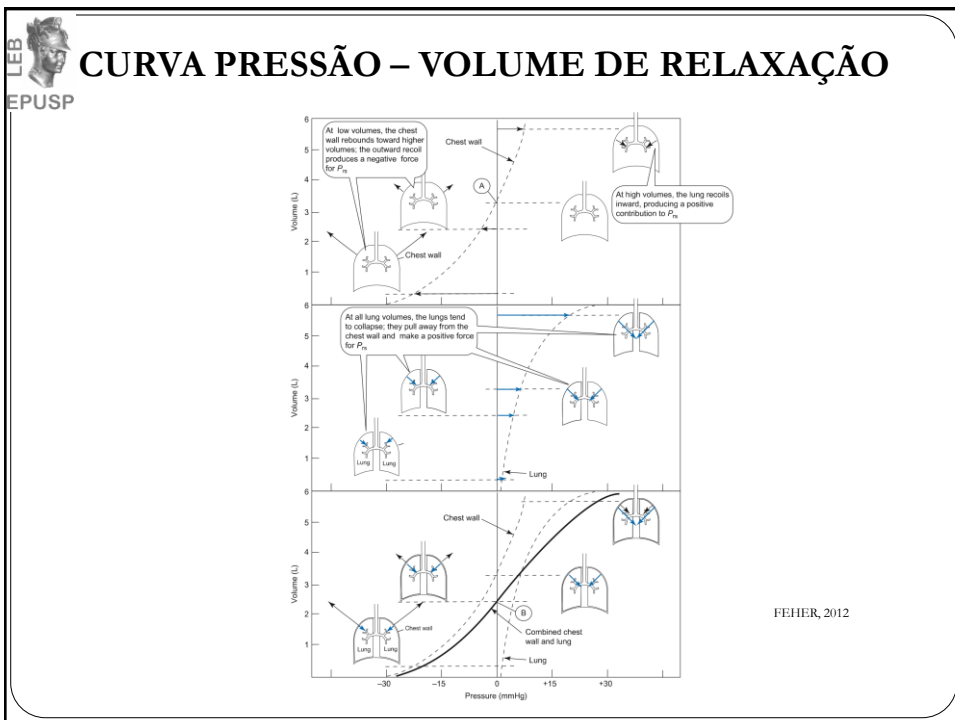
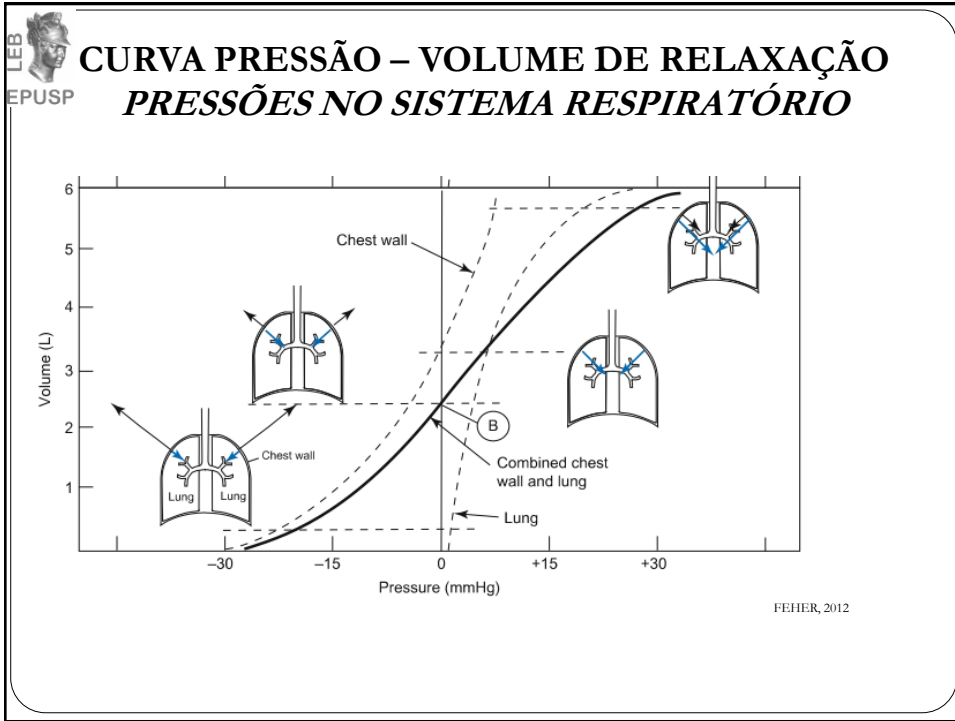
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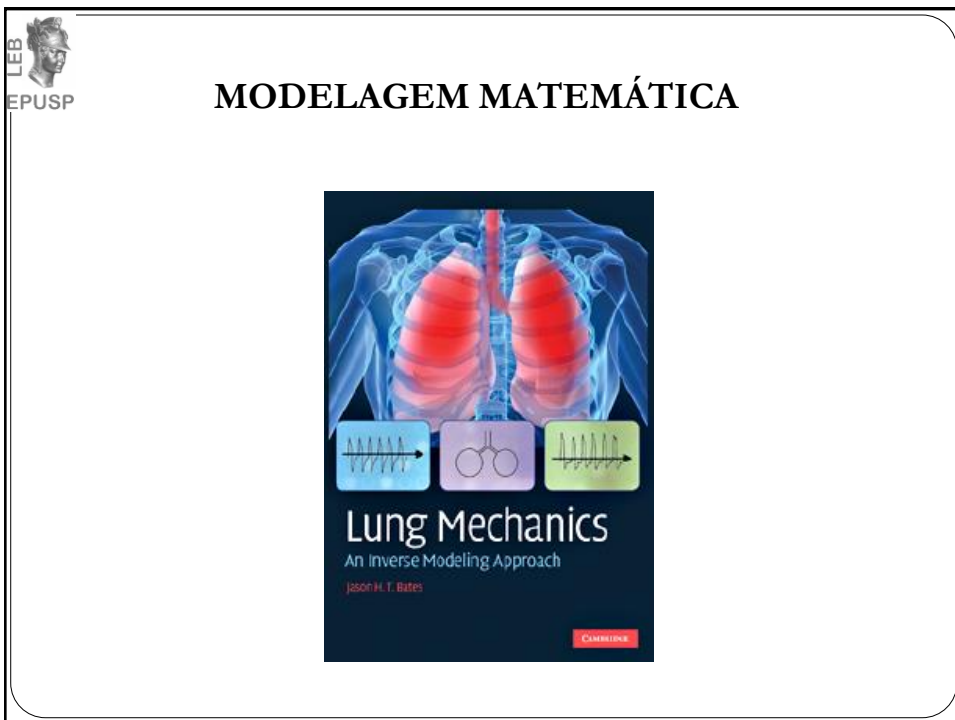
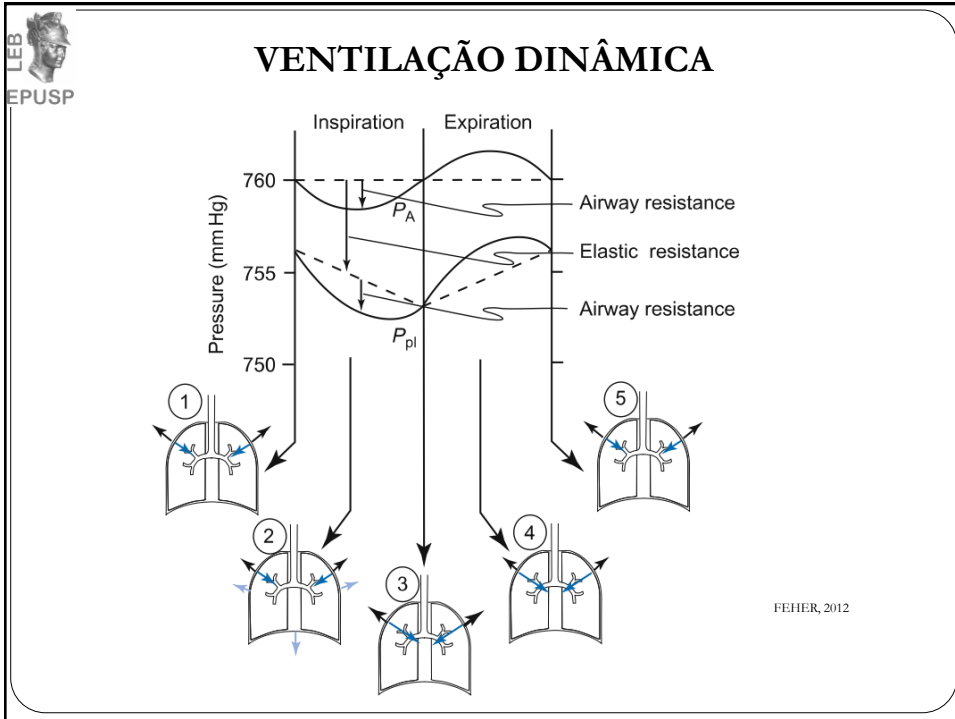
PRESSÕES

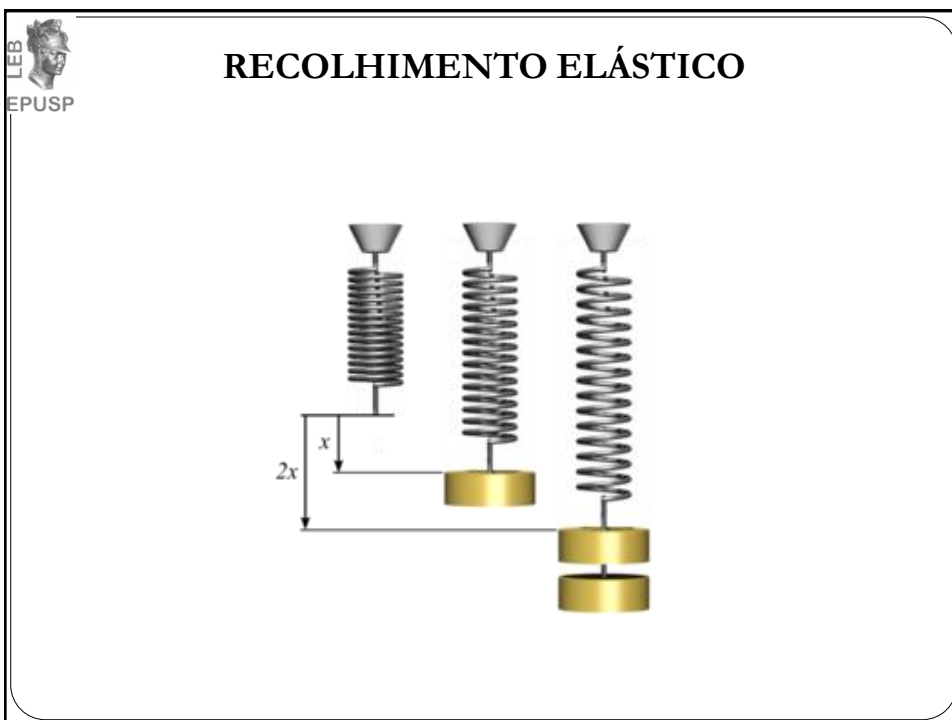
$P_A - P_B = P_{rs}$
 $P_{pl} - P_B = P_{chest\ wall}$
 $P_A - P_{pl} = P_{lung}$

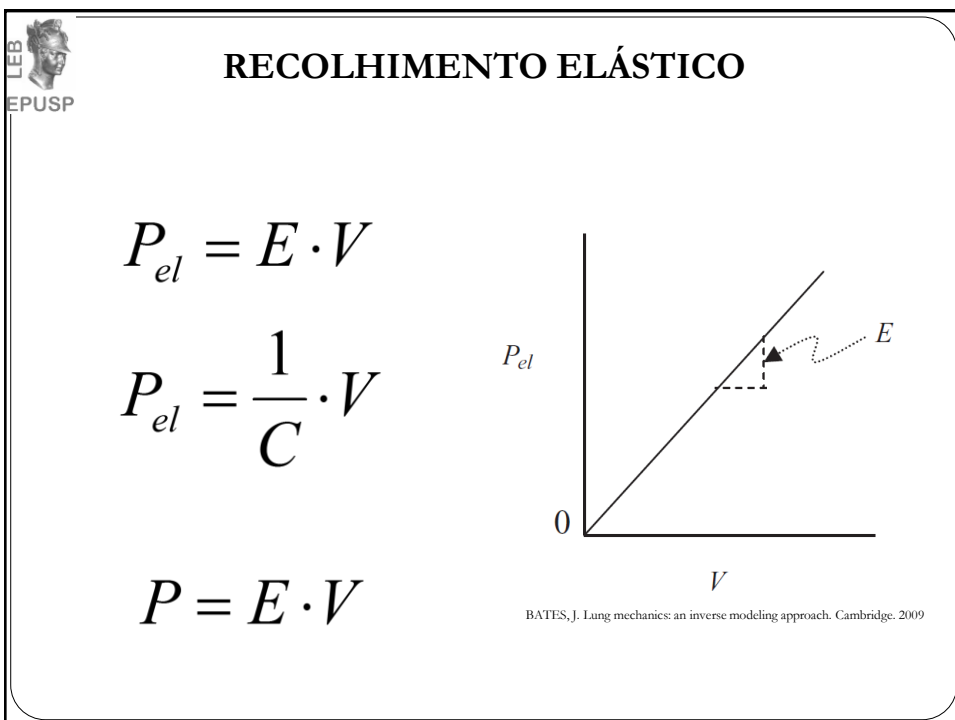
FEHER, 2012





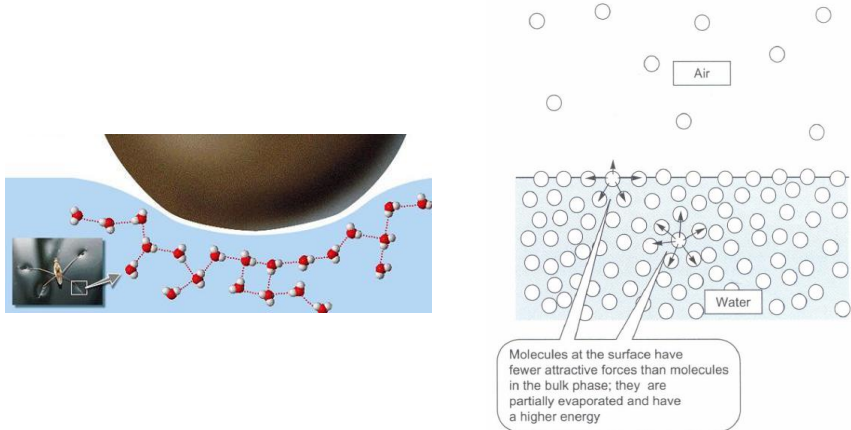






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TENSÃO SUPERFICIAL




Molecules at the surface have fewer attractive forces than molecules in the bulk phase; they are partially evaporated and have a higher energy

FEHER, 2012

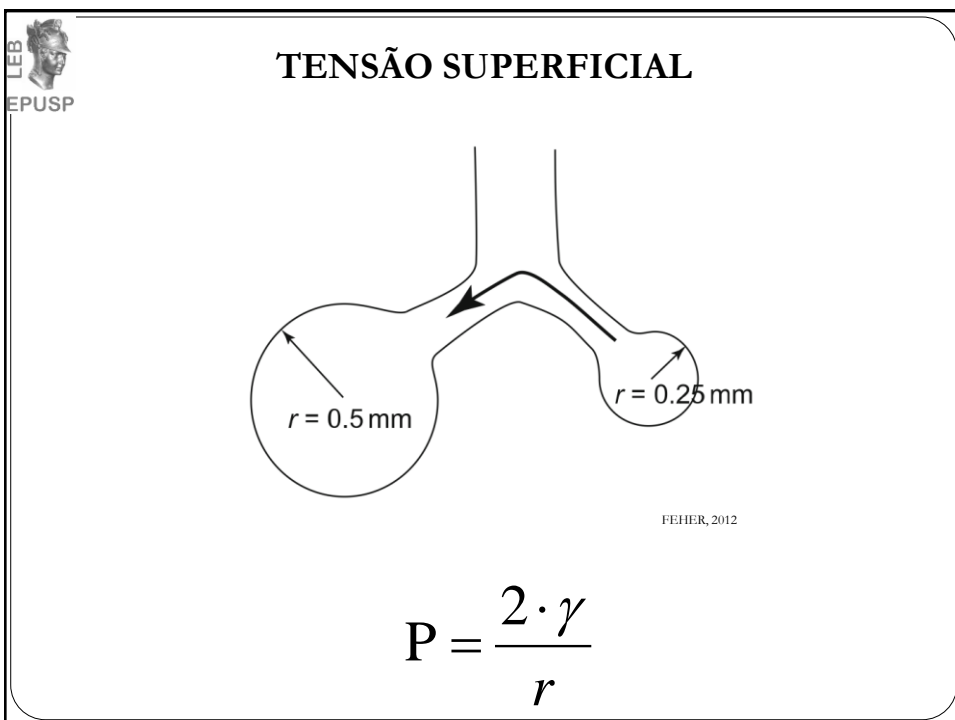
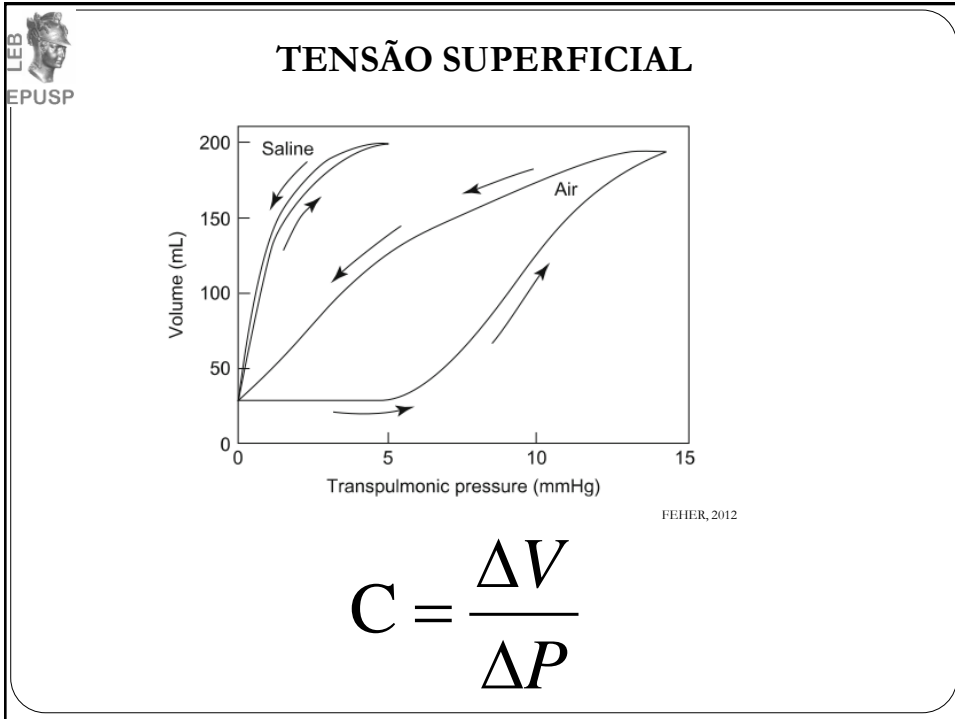
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TENSÃO SUPERFICIAL

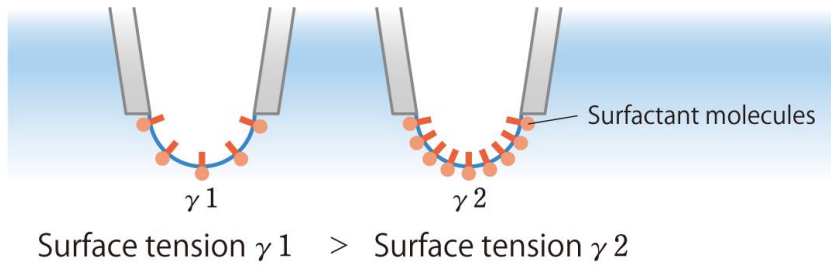


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$$P = \frac{2 \cdot \gamma}{r}$$

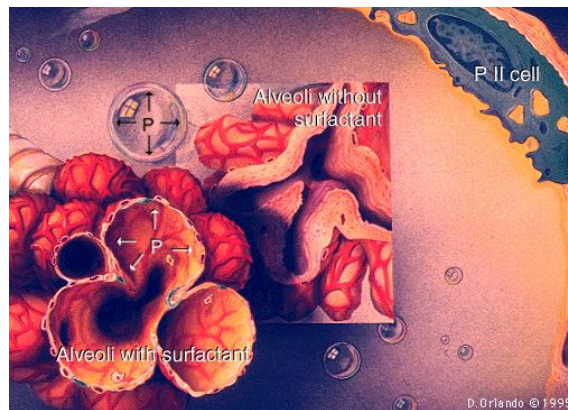


TENSÃO SUPERFICIAL

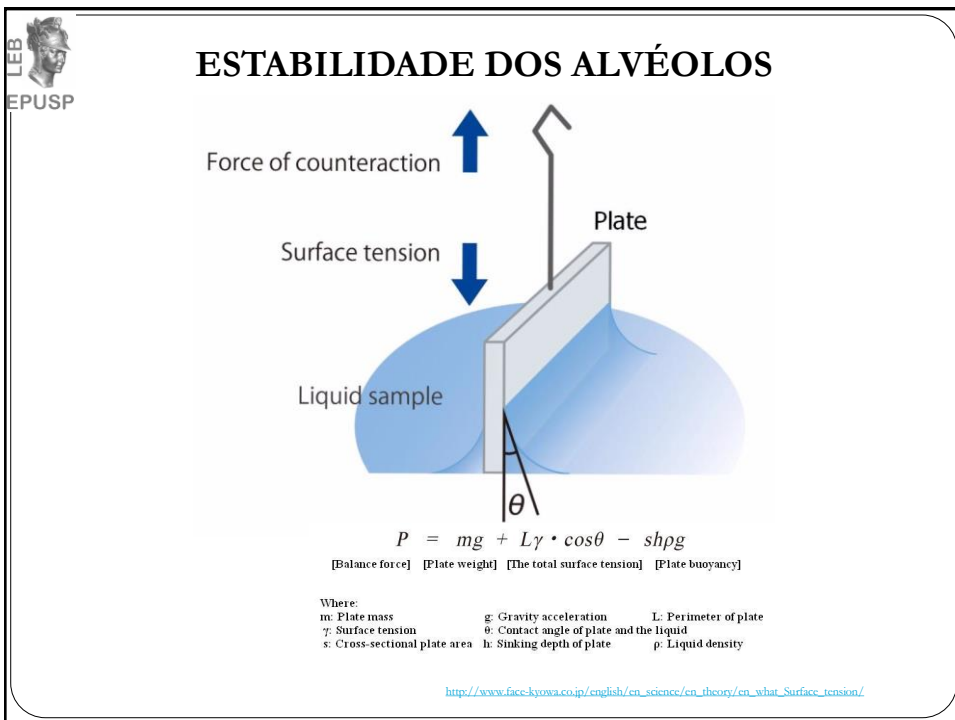
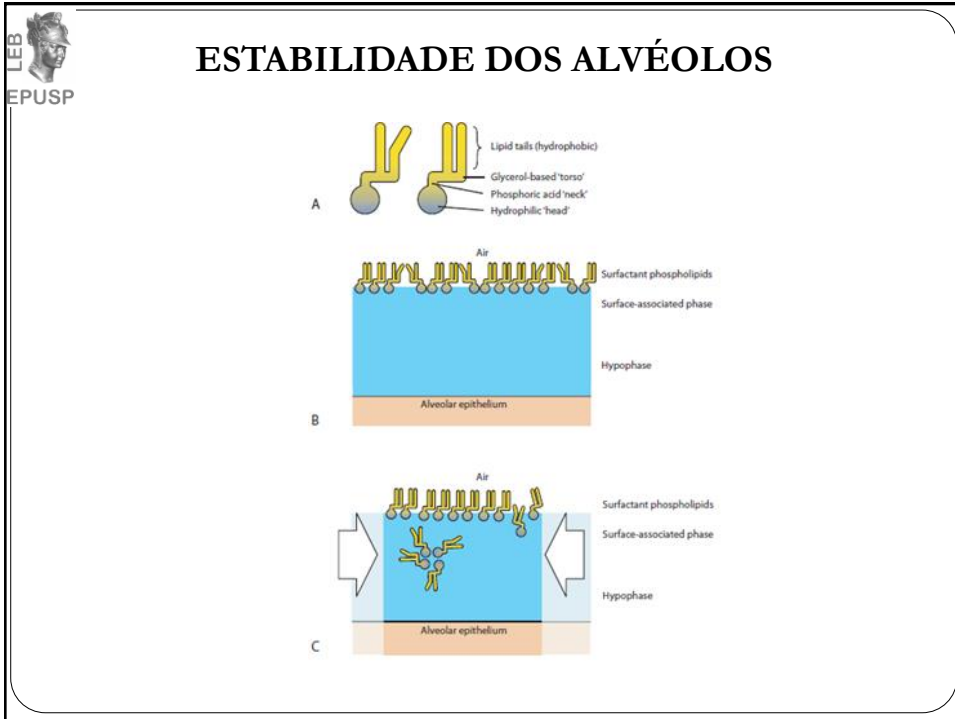


http://www.face-kyowa.co.jp/english/en_science/en_theory/en_what_Surface_tension/img08.jpg

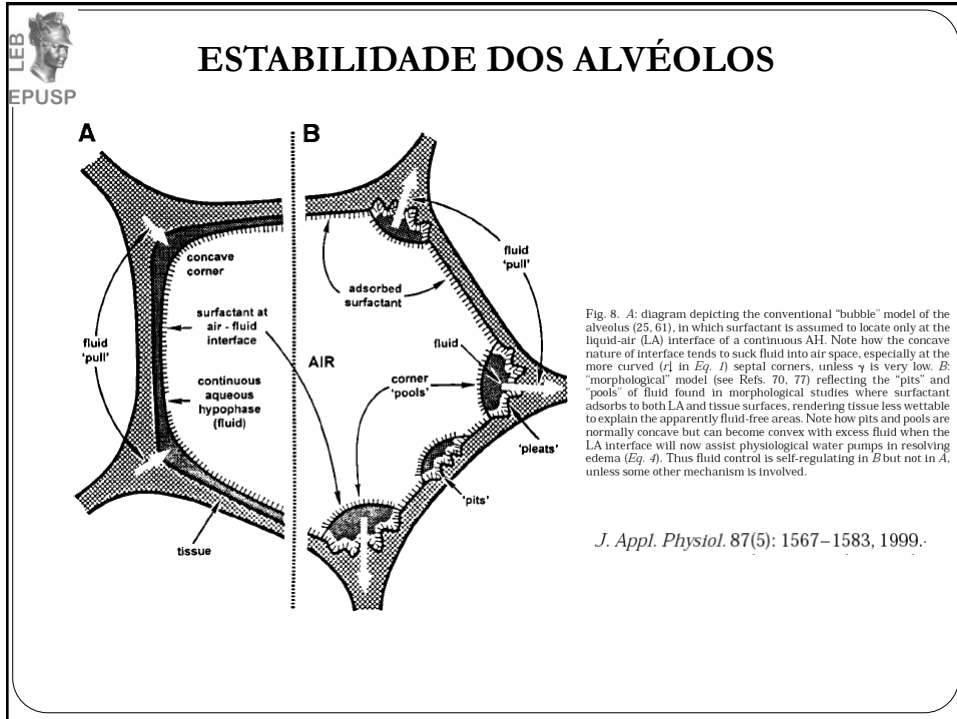
ESTABILIDADE DOS ALVÉOLOS



http://oac.med.jhmi.edu/res_phys/Encyclopedia/Surfactant/Surfactant.HTML







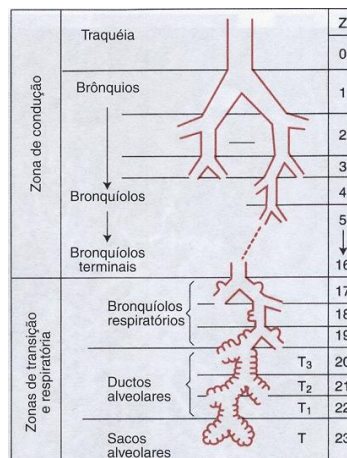


RESISTÊNCIA DAS VIAS AÉREAS

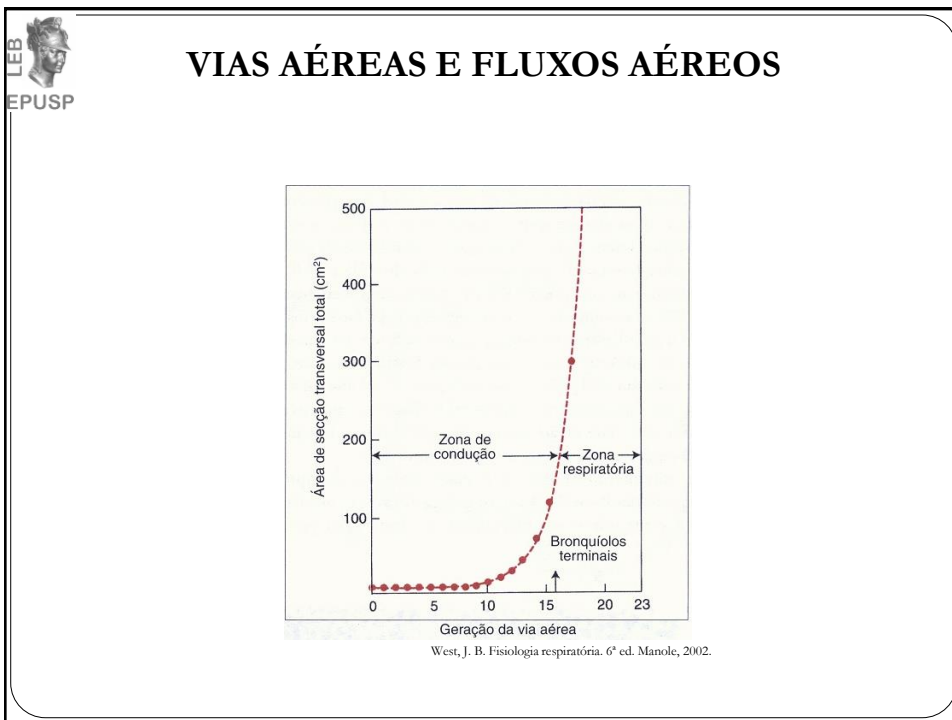
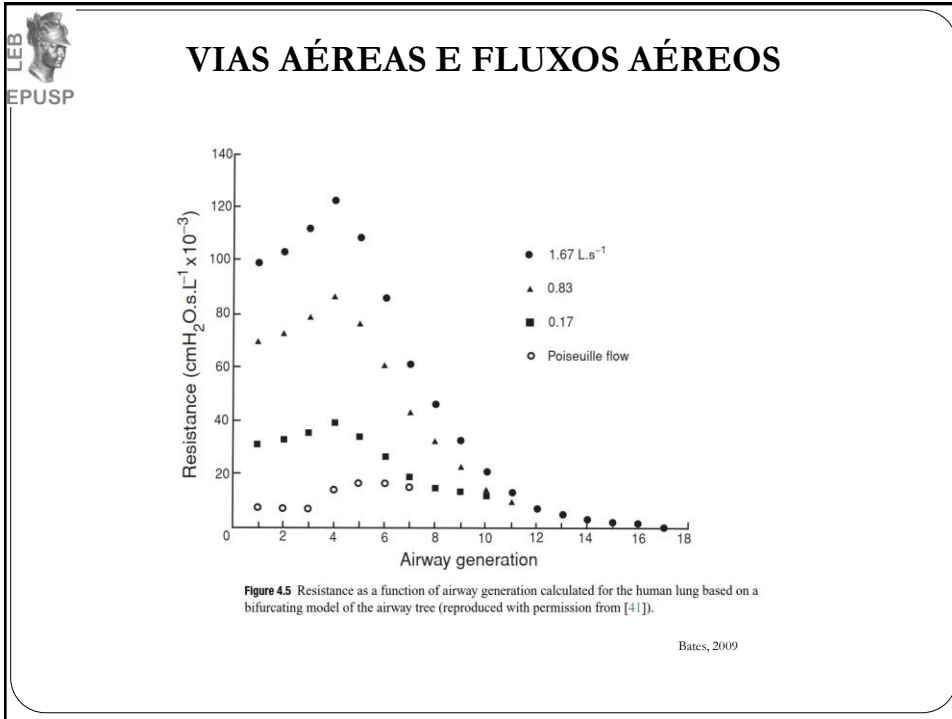
$$\text{Resistência} = \frac{8 \cdot \mu \cdot l}{\pi \cdot R^4}$$



VIAS AÉREAS E FLUXOS AÉREOS



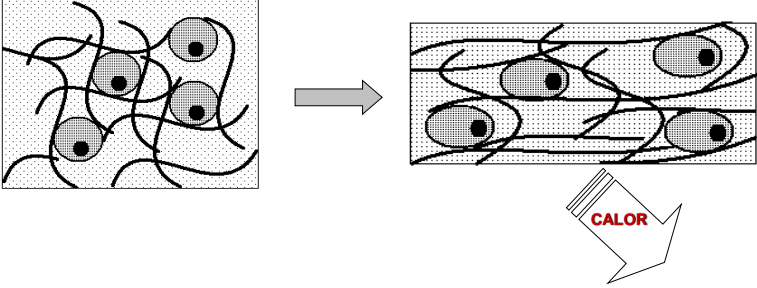
West, J. B. Fisiologia respiratória. 6ª ed. Manole, 2002.



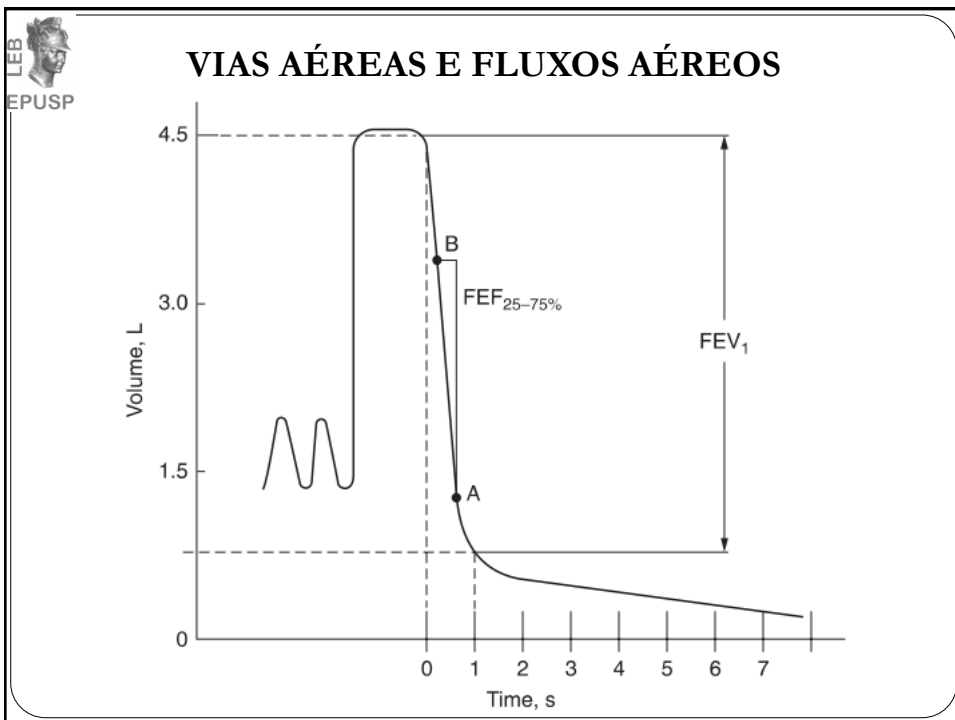
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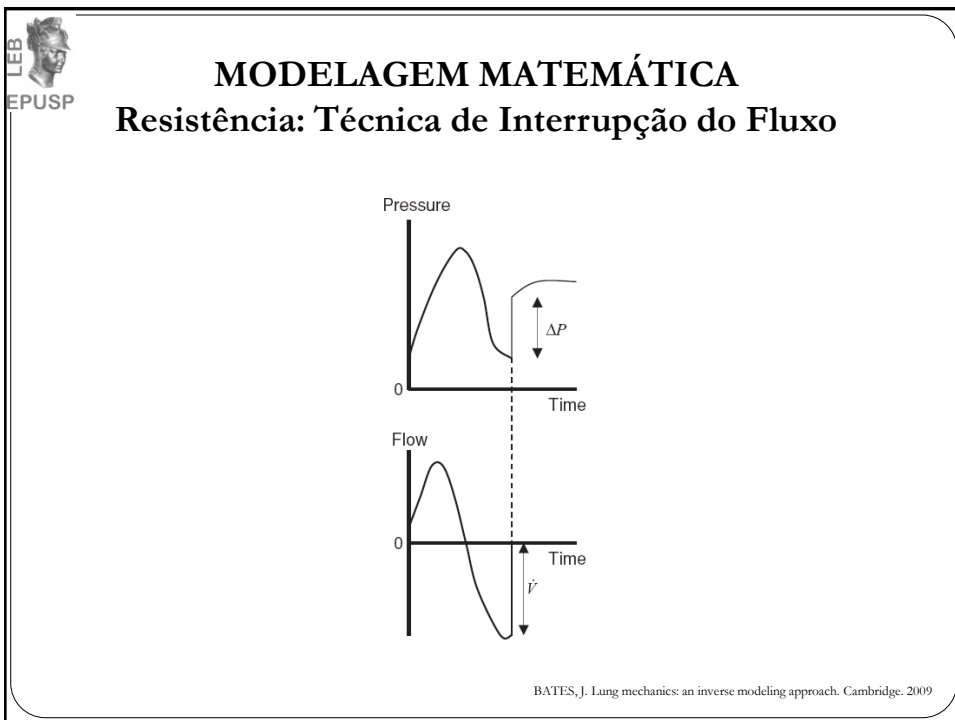
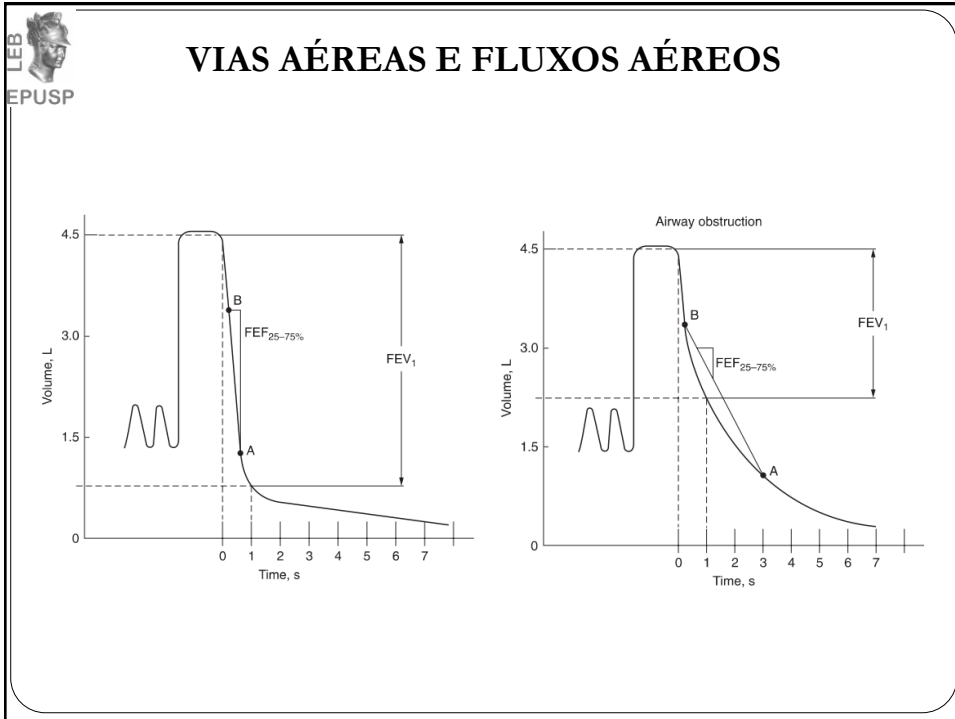
RESISTÊNCIA DOS TECIDOS PULMONARES

Tecido apresenta resistência



Bates, 2009

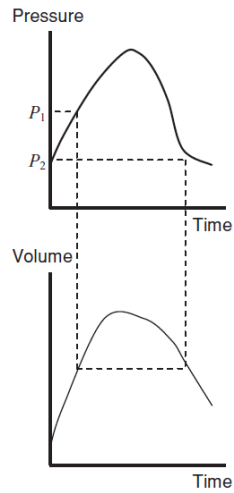






MODELAGEM MATEMÁTICA

Resistência: Método de Isovolume

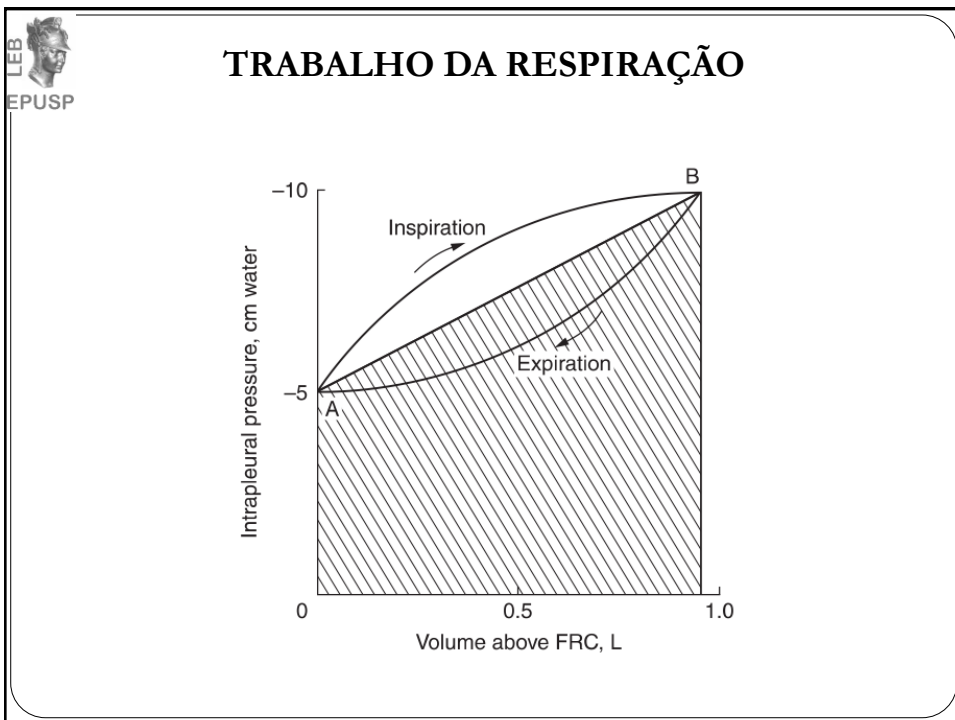
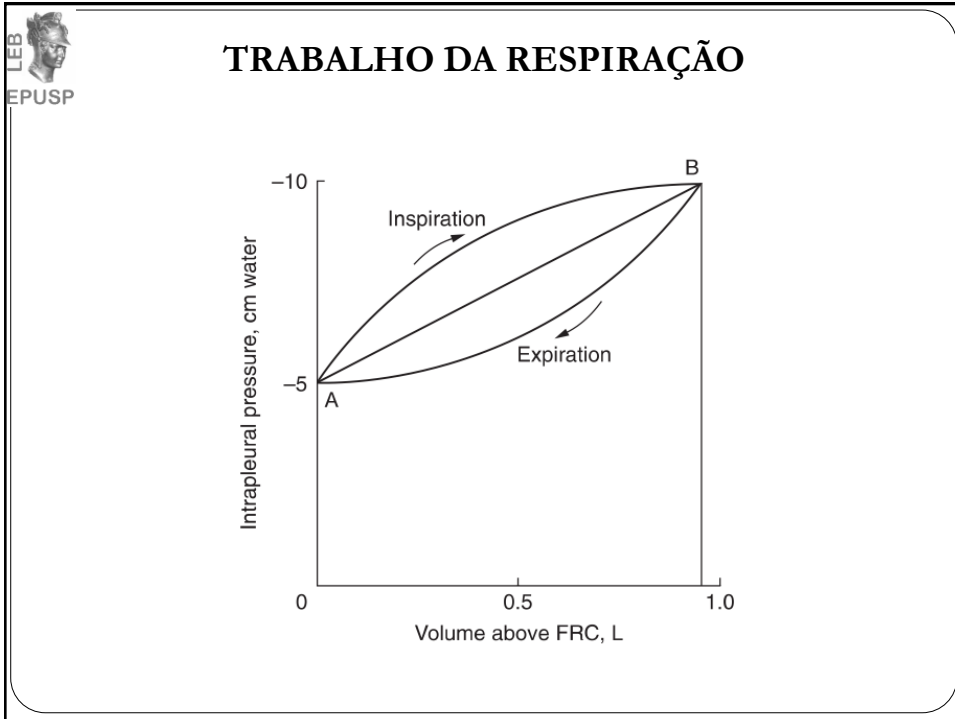


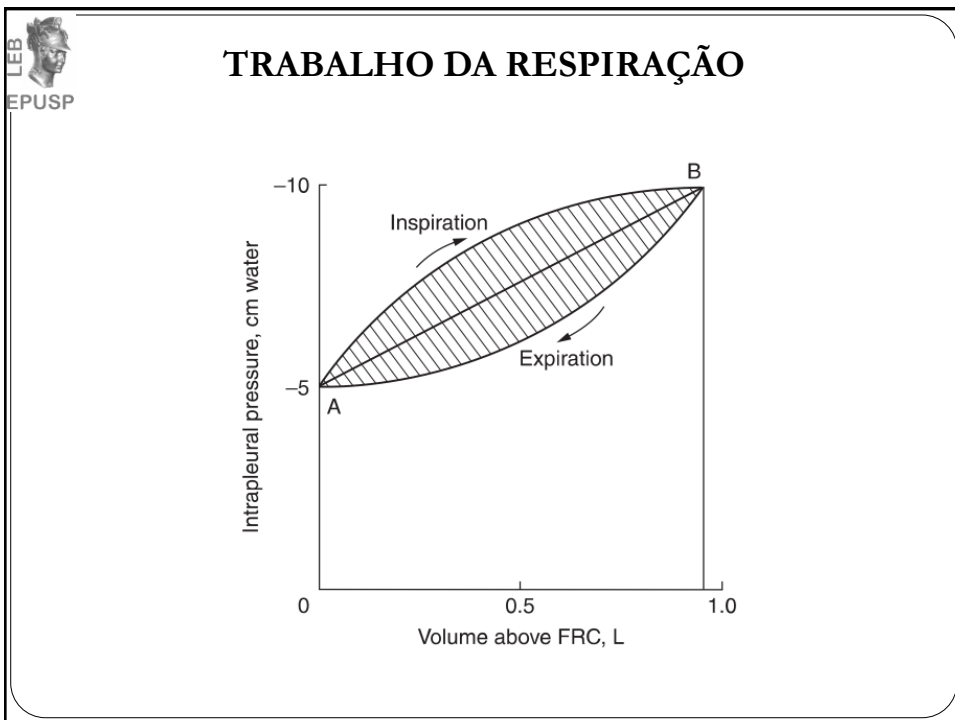
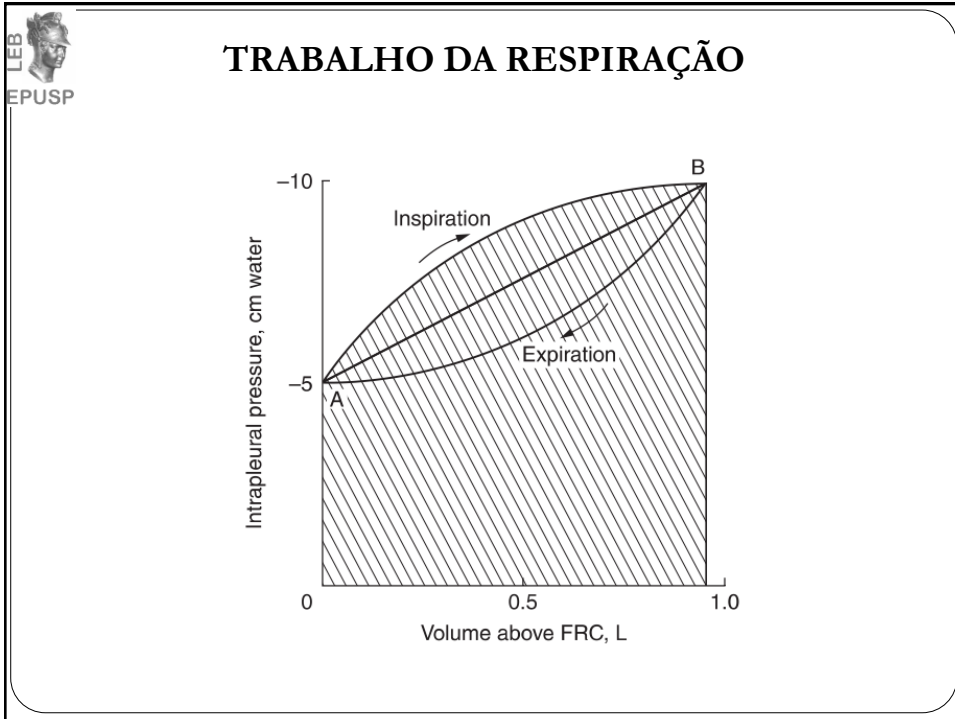
BATES, J. Lung mechanics: an inverse modeling approach. Cambridge, 2009



TRABALHO DA RESPIRAÇÃO

$$W_{a \rightarrow b} = \int_a^b P dV$$

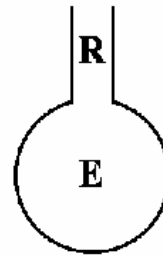
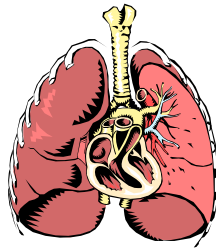






MODELAGEM MATEMÁTICA

Modelo linear de um compartimento



MODELAGEM MATEMÁTICA

Modelo linear de um compartimento

$$P = R \cdot \dot{V} + E \cdot V + P_0$$

Pressão = R · fluxo + E · volume + Pressão residual



MODELAGEM MATEMÁTICA
Modelo linear de um compartimento

$$P = R \cdot \dot{V} + E \cdot V + P_0$$

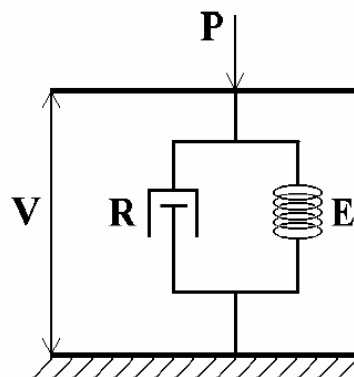
“Equação do Movimento”

$$C = \frac{1}{E}$$

$$P = R \cdot \dot{V} + \frac{1}{C} \cdot V + P_0$$



MODELAGEM MATEMÁTICA
Modelo linear de um compartimento

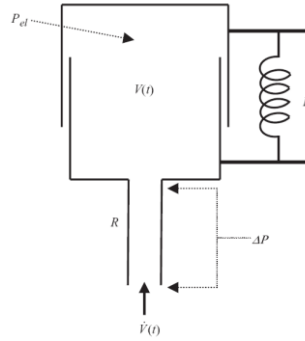


$$P = R \cdot \dot{V} + E \cdot V + P_0$$



MODELAGEM MATEMÁTICA

Modelo linear de um compartimento



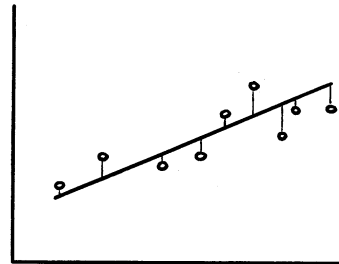
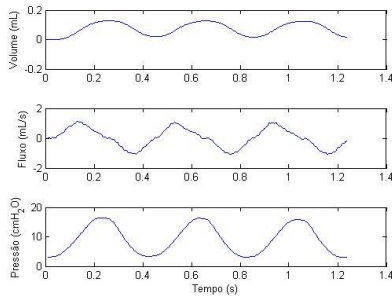
BATES, J. Lung mechanics: an inverse modeling approach. Cambridge. 2009

$$P = R \cdot \dot{V} + E \cdot V + P_0$$



MODELAGEM MATEMÁTICA

Modelo linear de um compartimento



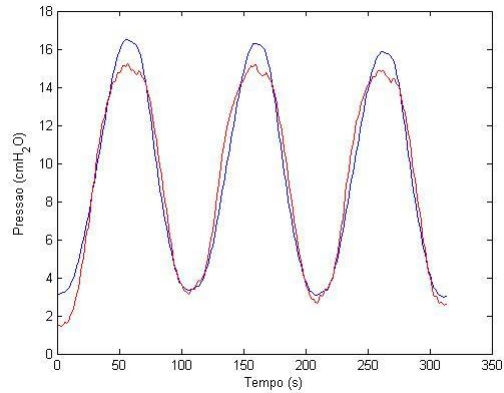
$$P = R \cdot \dot{V} + E \cdot V + P_0$$



MODELAGEM MATEMÁTICA

Modelo linear de um compartimento

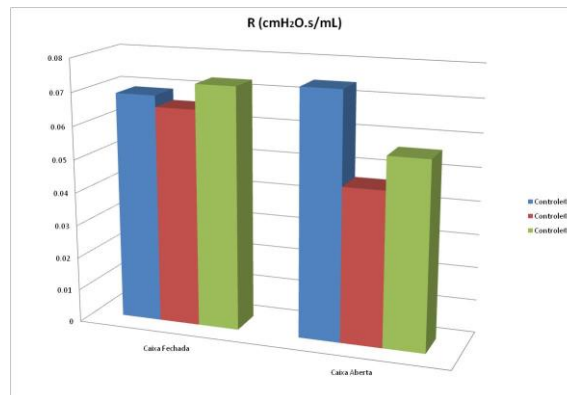
$$P = R \cdot \dot{V} + E \cdot V + P_0$$



MODELAGEM MATEMÁTICA

Modelo linear de um compartimento

$$P = R \cdot \dot{V} + E \cdot V + P_0$$

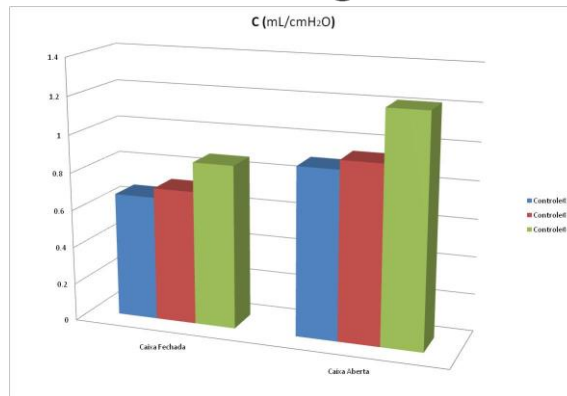




MODELAGEM MATEMÁTICA

Modelo linear de um compartimento

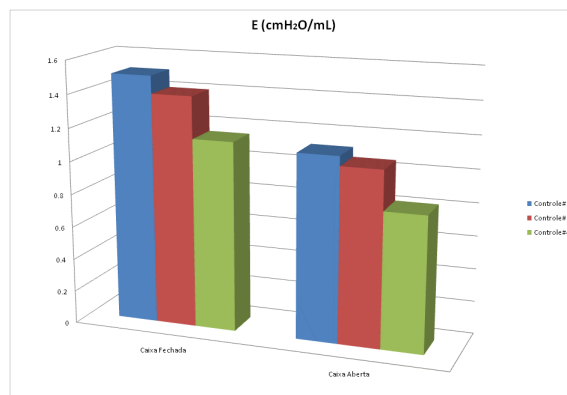
$$P = R \cdot \dot{V} + \frac{1}{C} \cdot V + P_0$$



MODELAGEM MATEMÁTICA

Modelo linear de um compartimento

$$P = R \cdot \dot{V} + E \cdot V + P_0$$

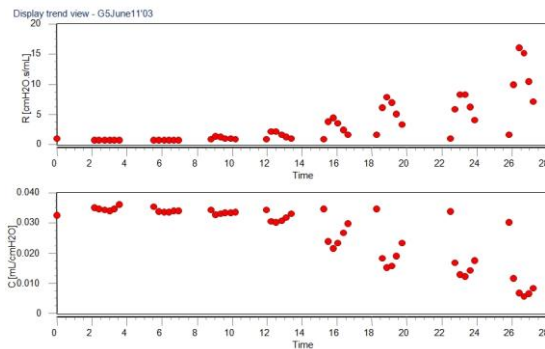




MODELAGEM MATEMÁTICA

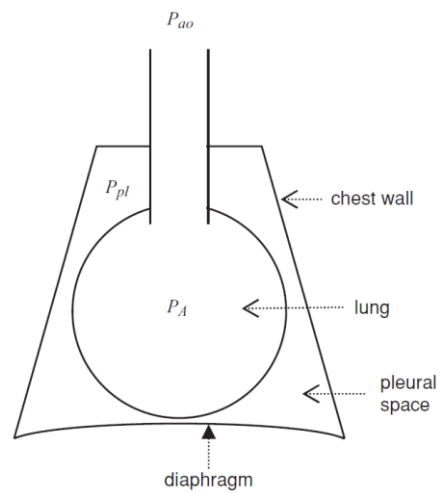
Modelo linear de um compartimento

$$P = R \cdot \dot{V} + \frac{1}{C} \cdot V + P_0$$

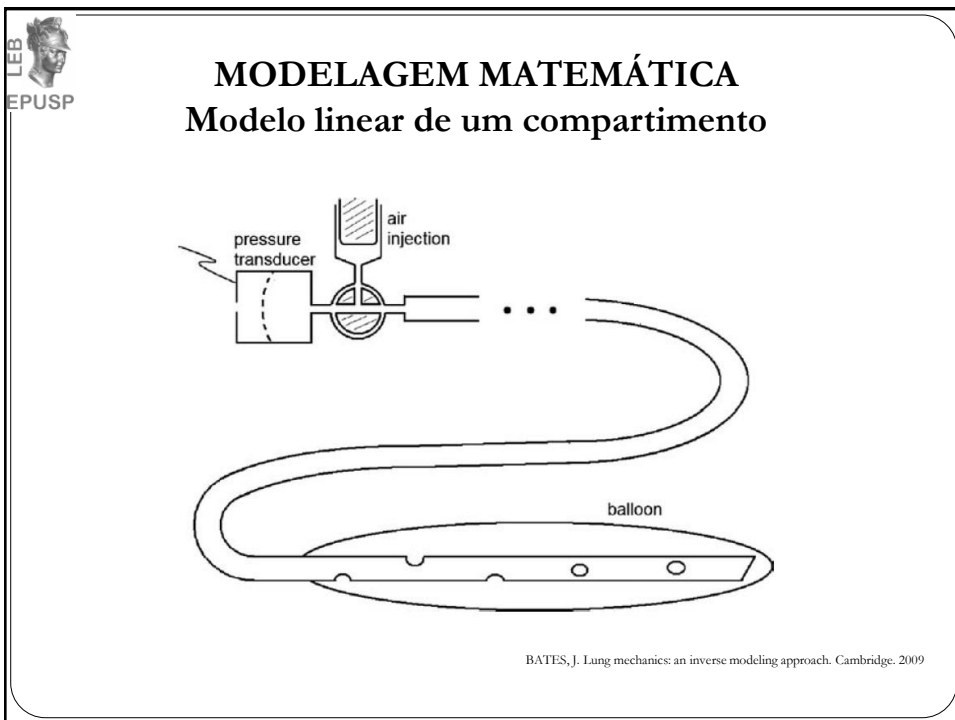
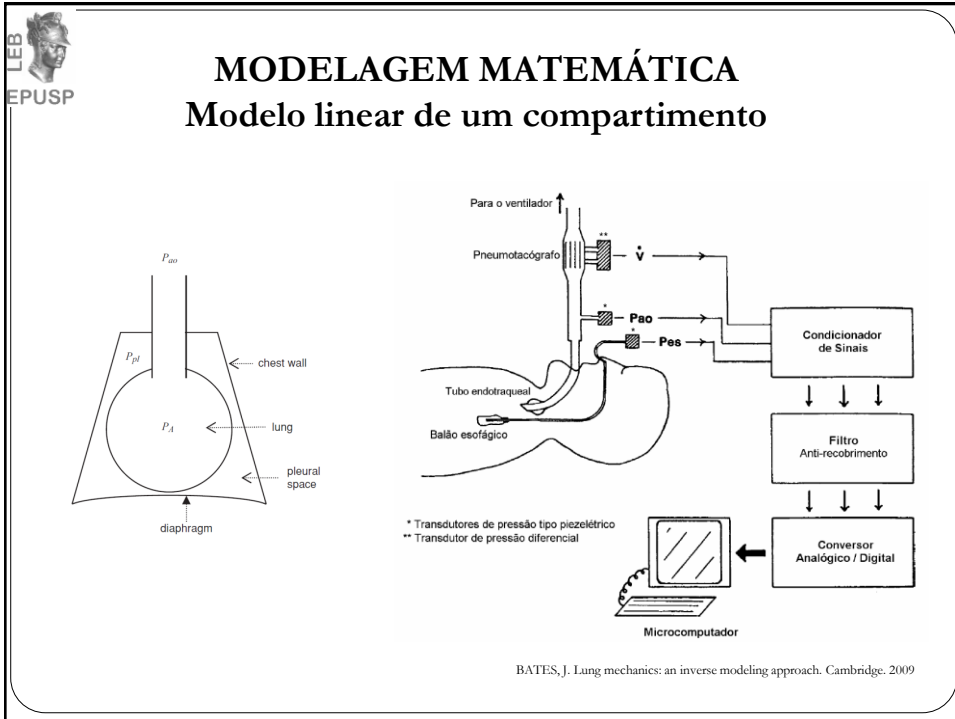


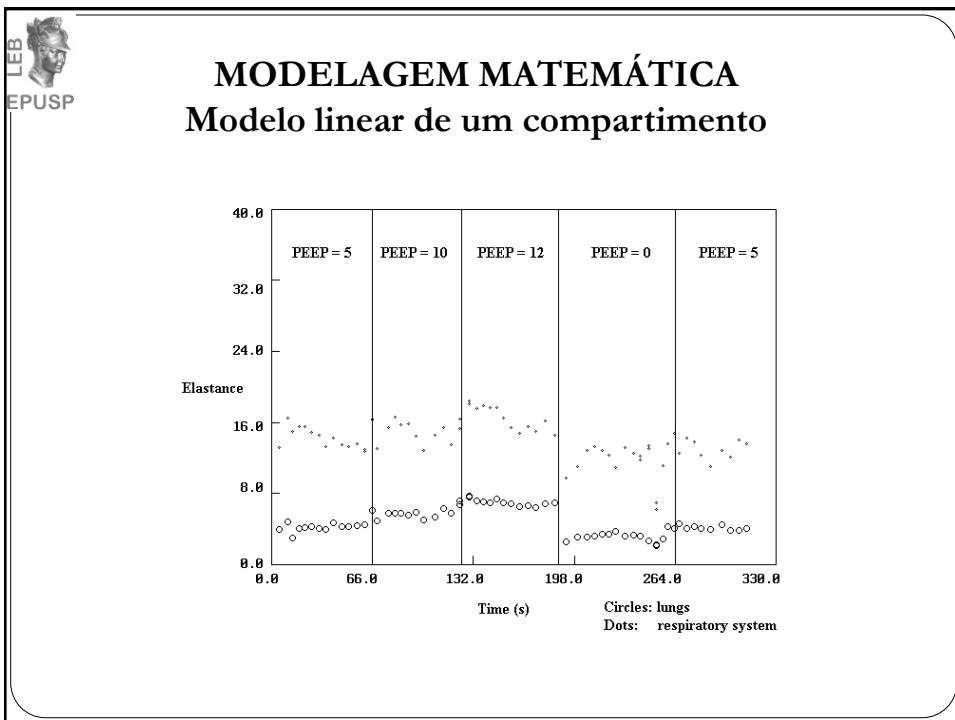
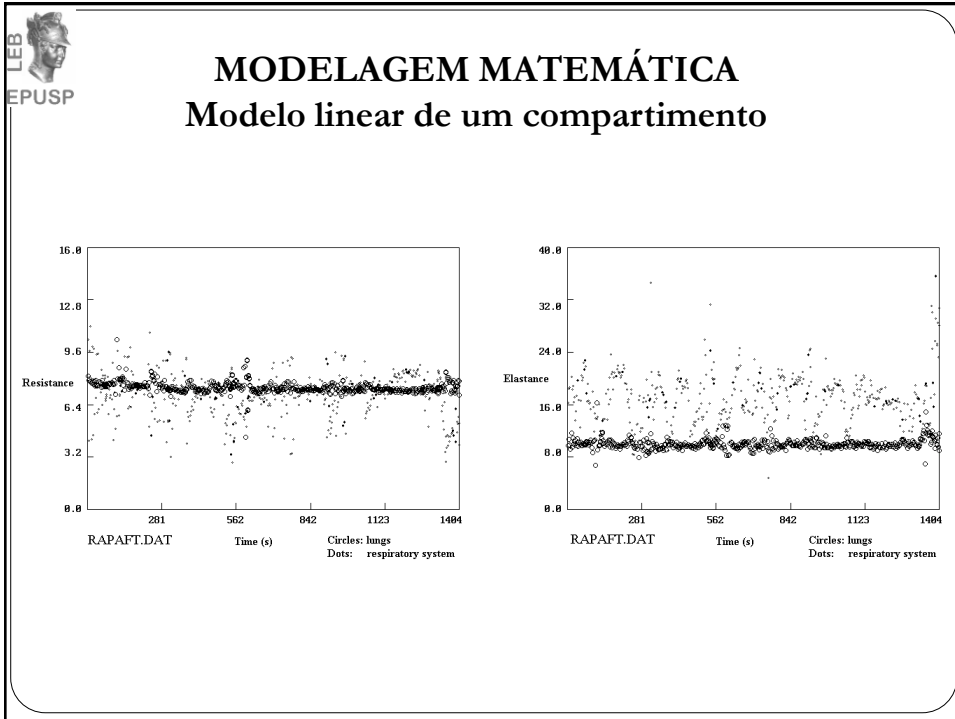
MODELAGEM MATEMÁTICA

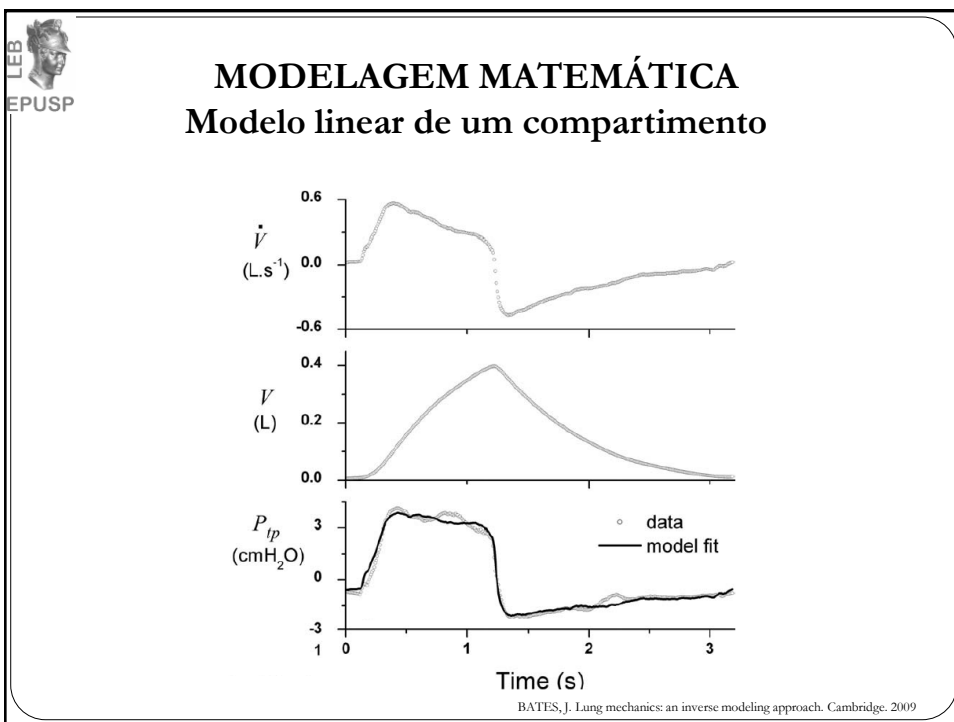
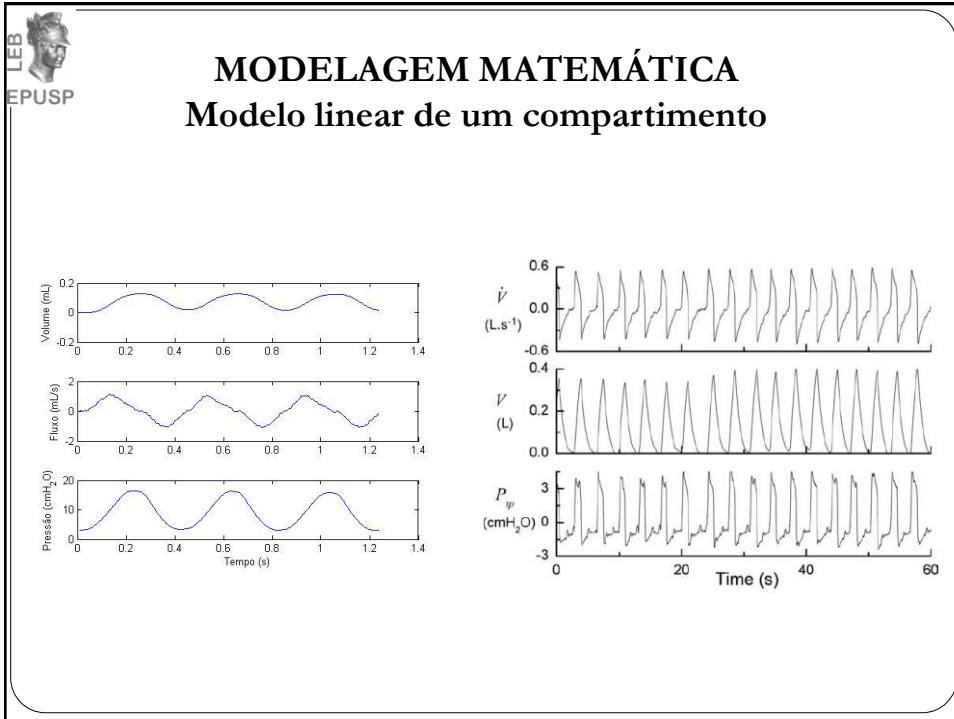
Modelo linear de um compartimento

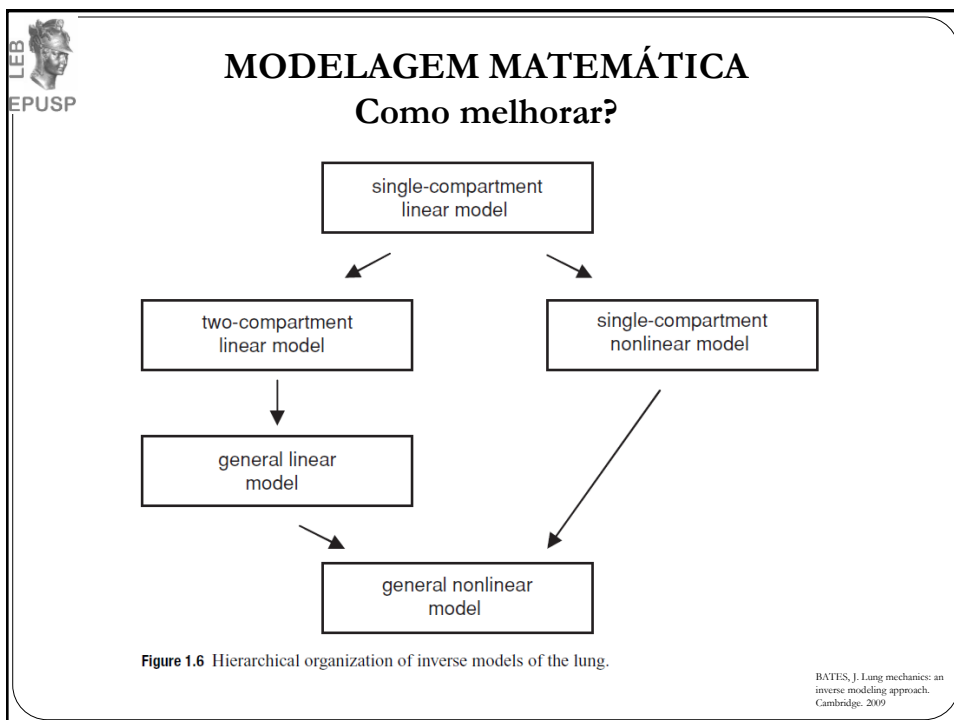
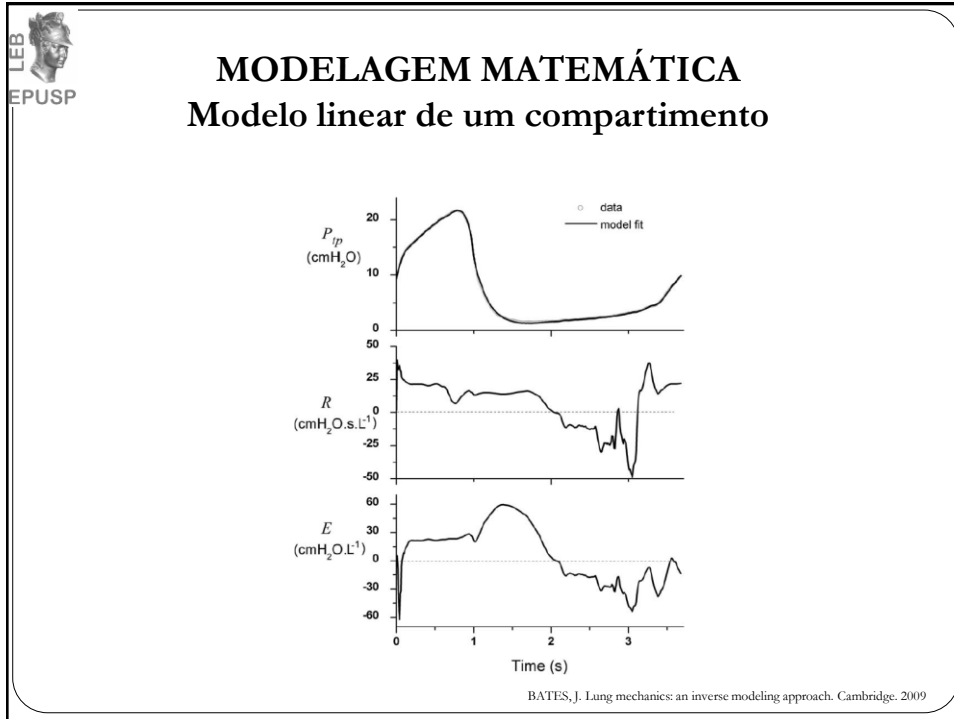


BATES, J. Lung mechanics: an inverse modeling approach. Cambridge. 2009











COMPORTAMENTO NÃO LINEAR

Resistência dependente do fluxo

$$\Delta P = K_1 \cdot \dot{V} + K_2 \cdot \dot{V} \cdot |\dot{V}|$$



COMPORTAMENTO NÃO LINEAR

Resistência dependente do fluxo

$$P_{tp} = E_L \cdot V + K_1 \cdot \dot{V} + K_2 \cdot \dot{V} \cdot |\dot{V}| + P_0$$



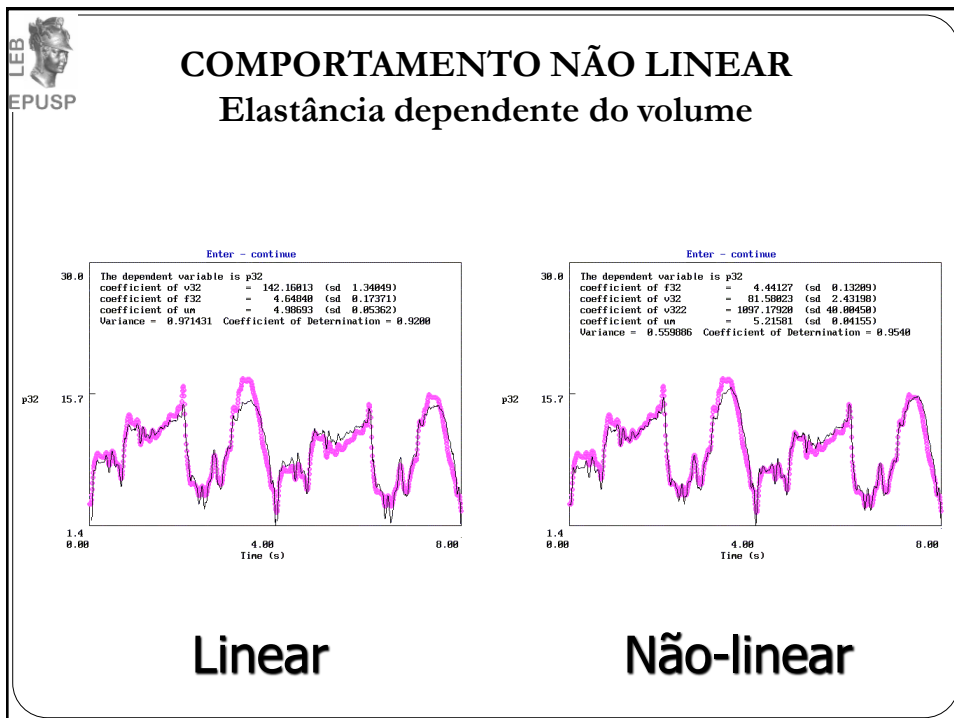
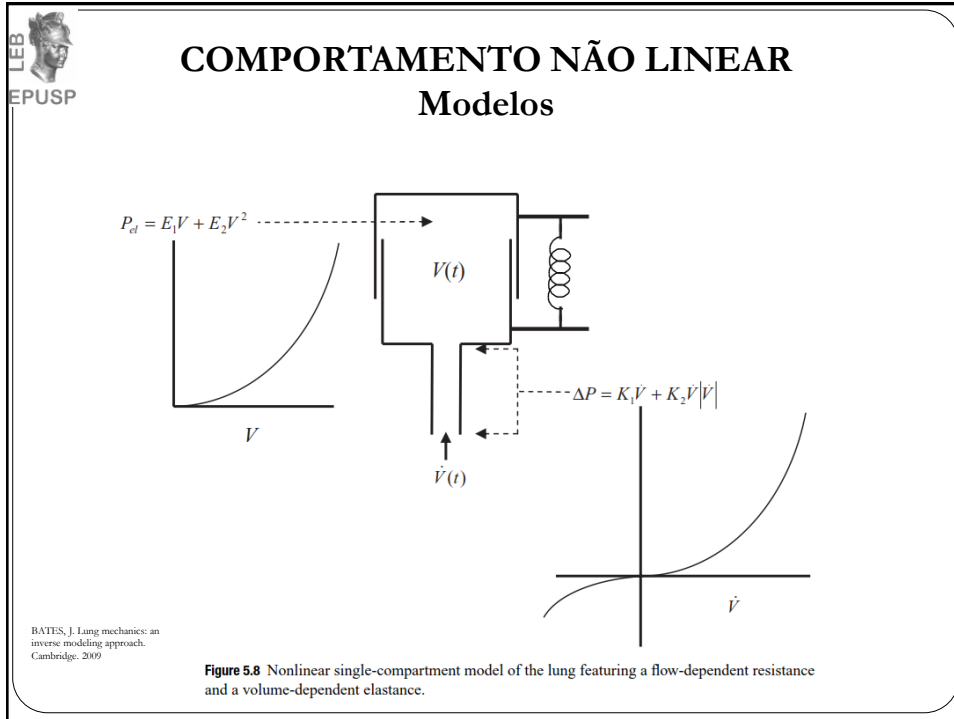
COMPORTAMENTO NÃO LINEAR
Elastância dependente do volume

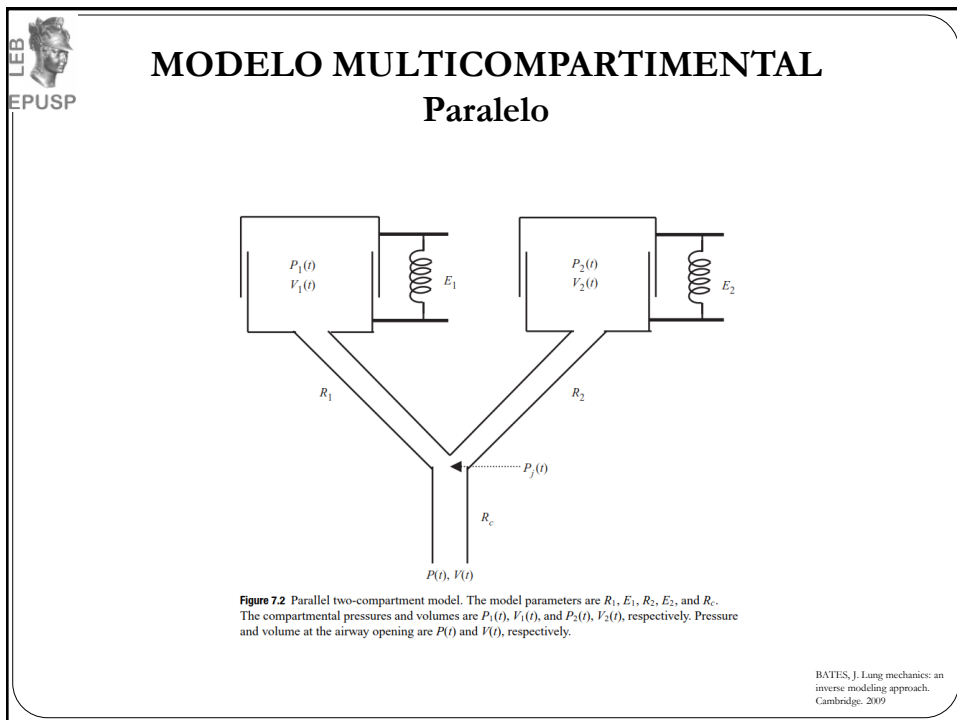
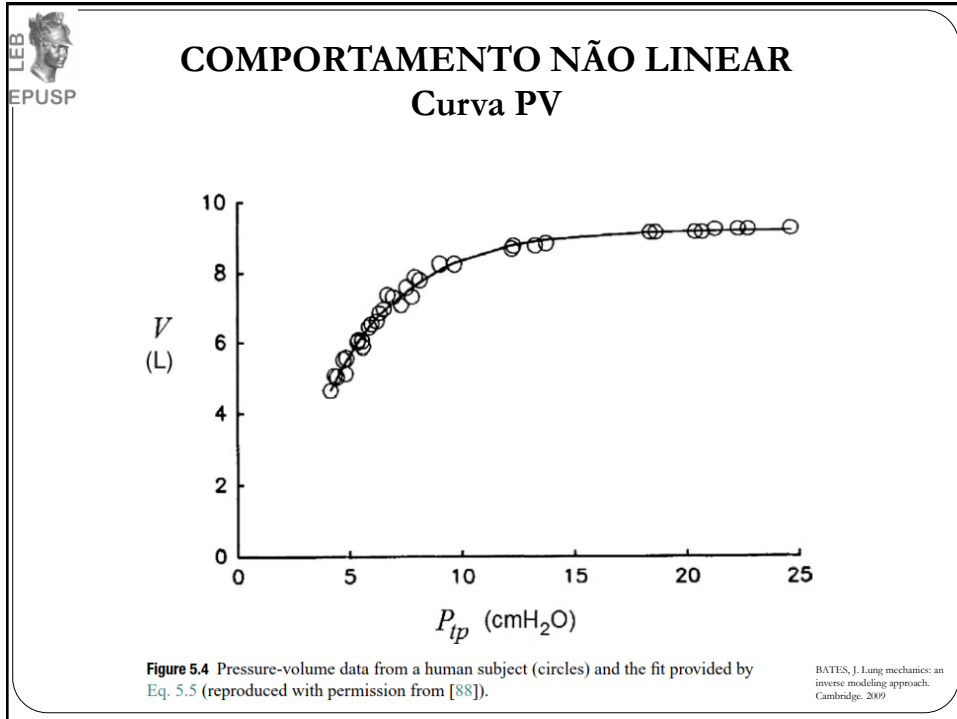
$$P_{el} = E_1 \cdot V + E_2 \cdot V^2$$

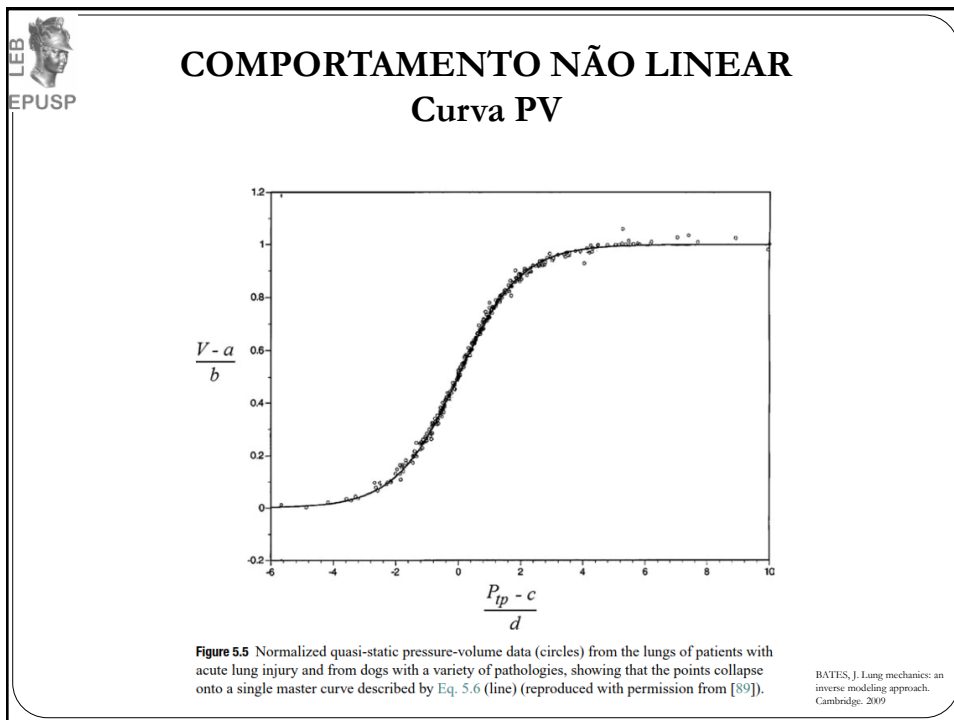
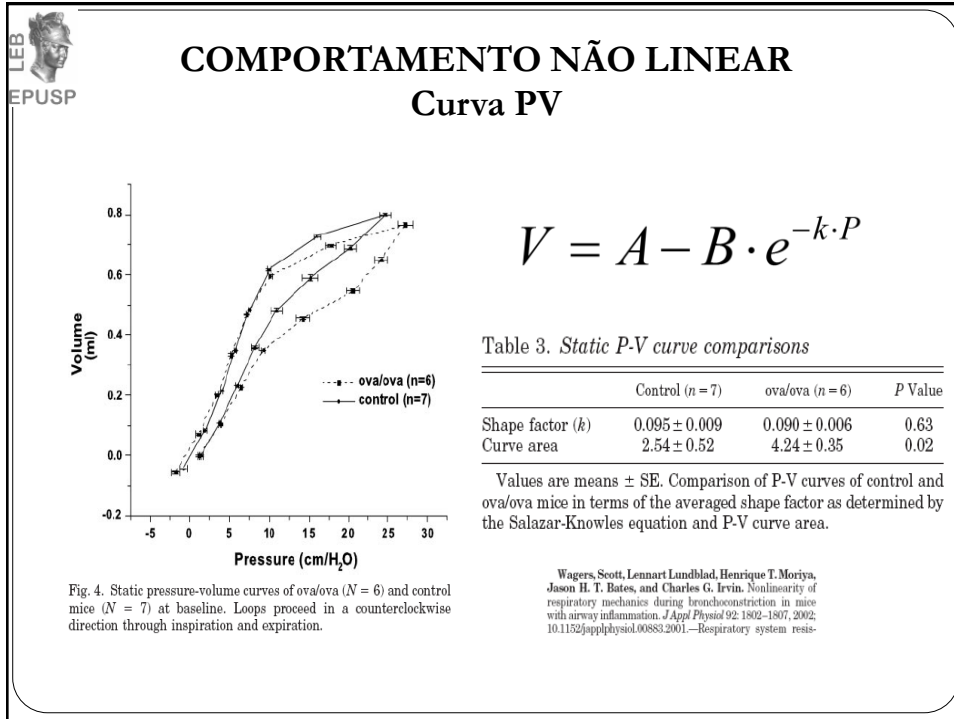


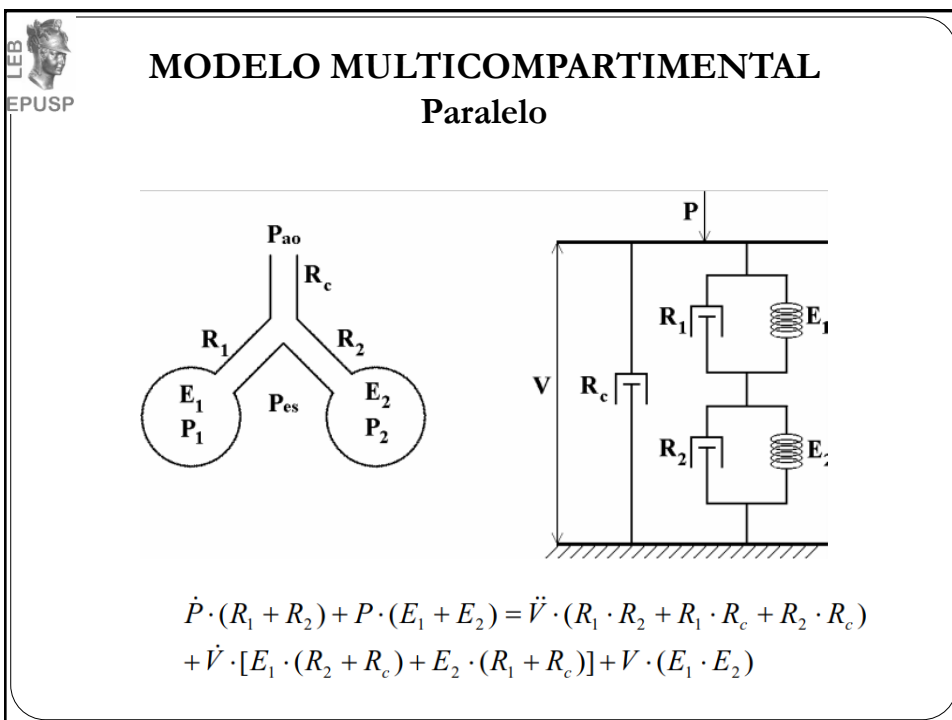
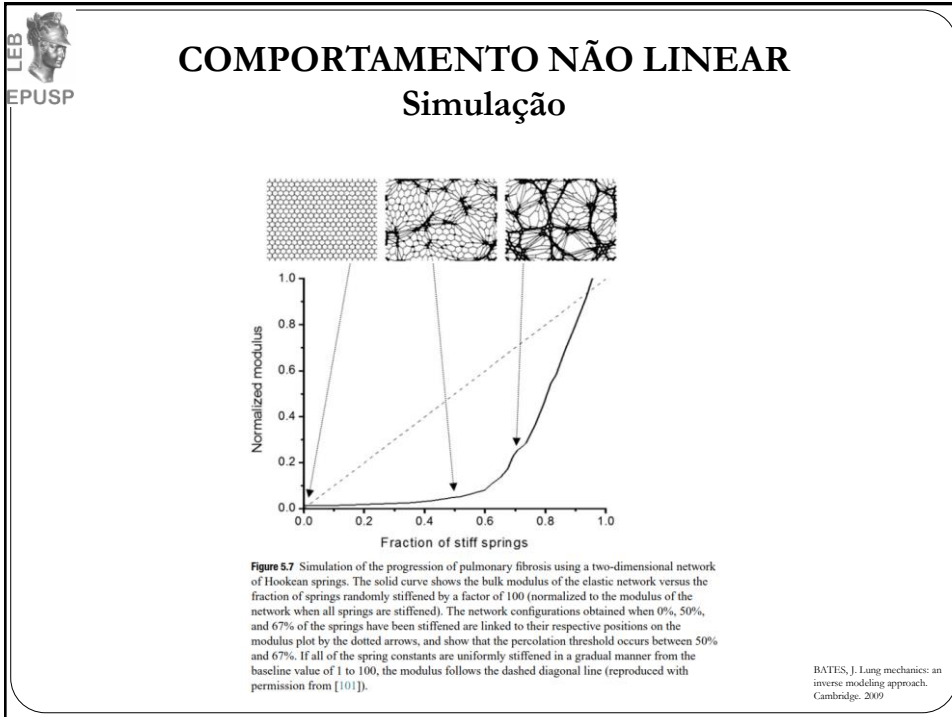
COMPORTAMENTO NÃO LINEAR
Elastância dependente do volume

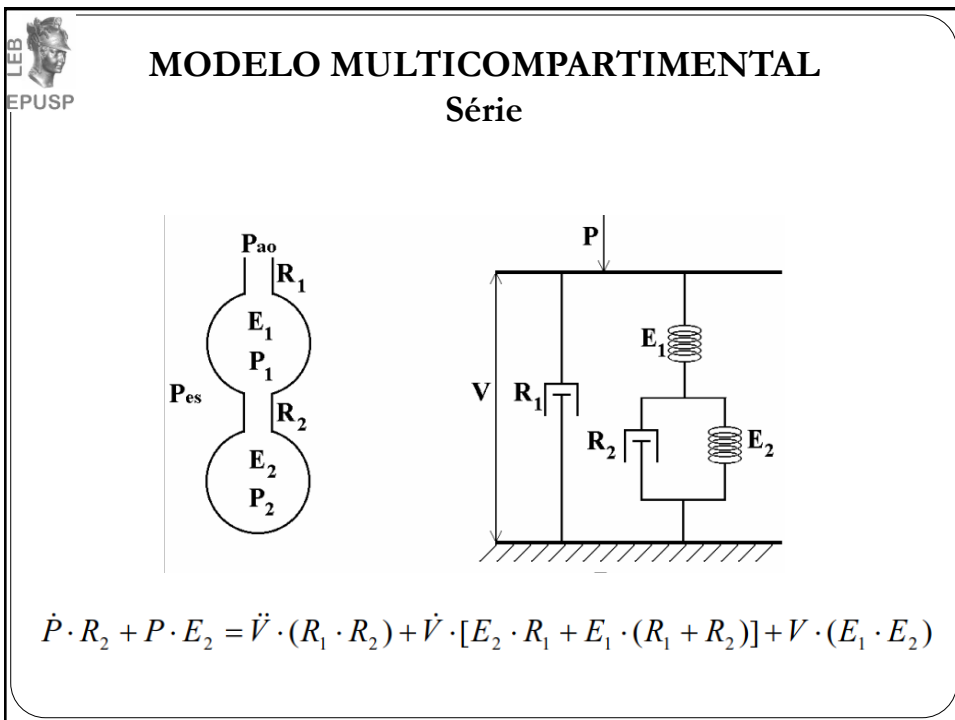
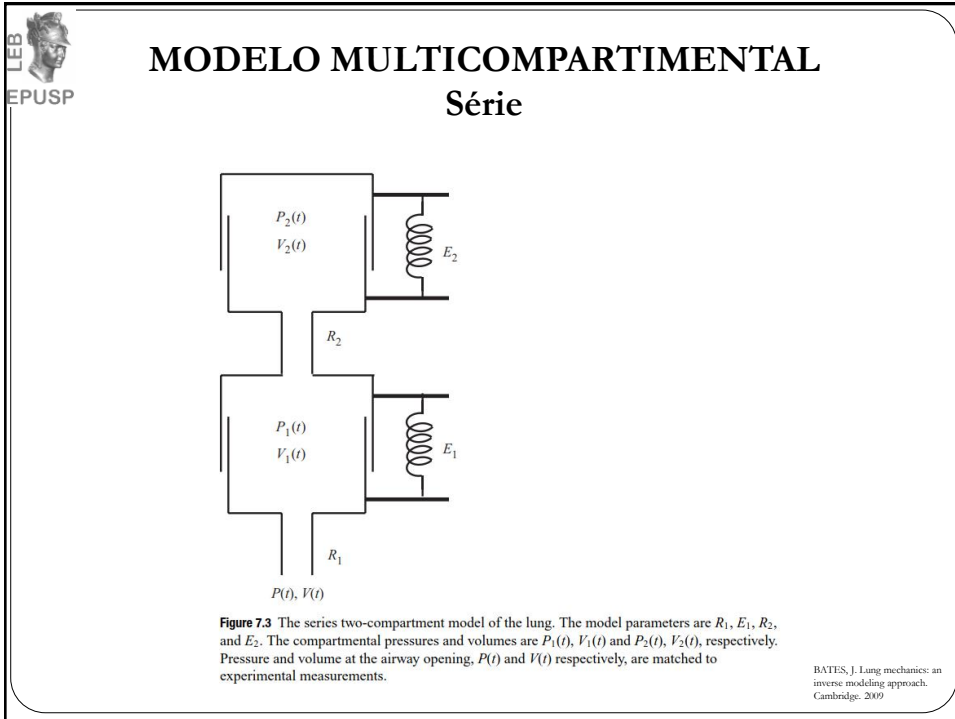
$$P_{tp} = R_L \cdot \dot{V} + E_1 \cdot V + E_2 \cdot V^2 + P_0$$

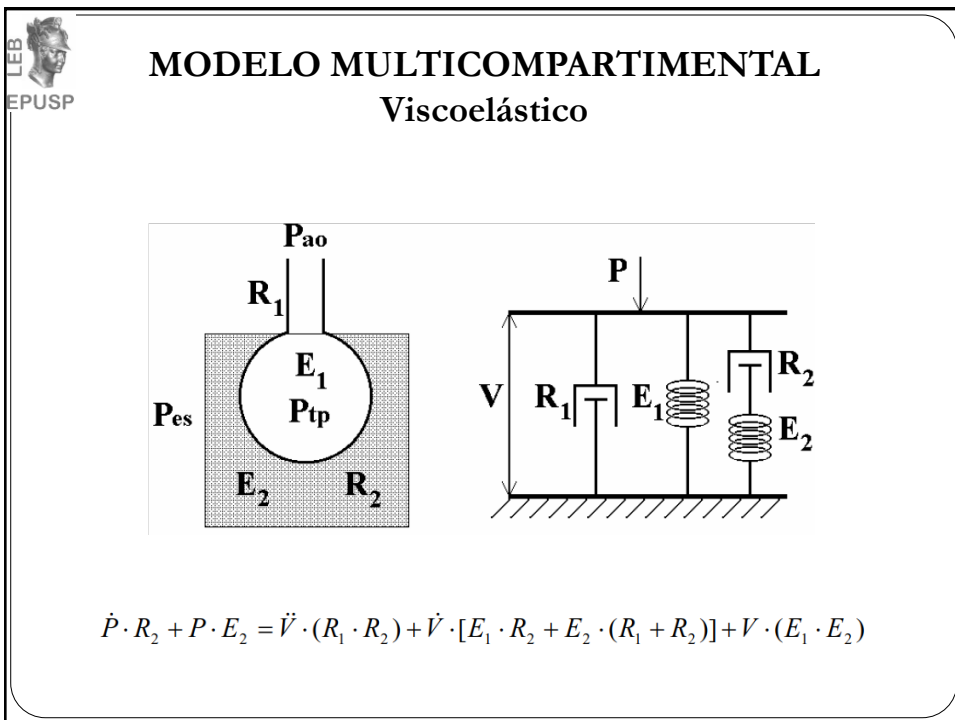
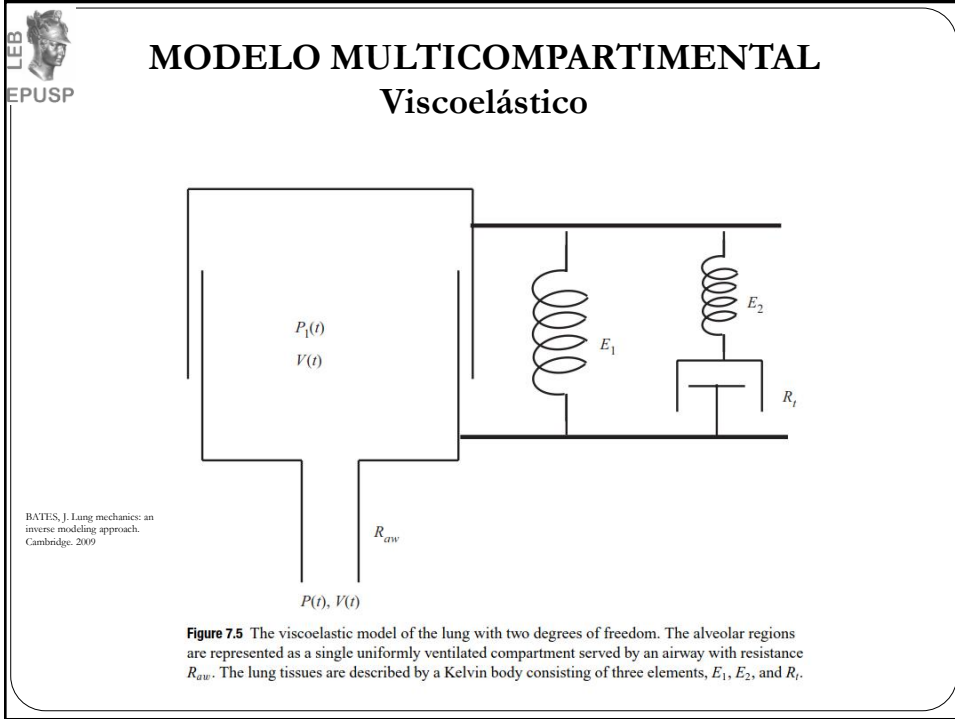


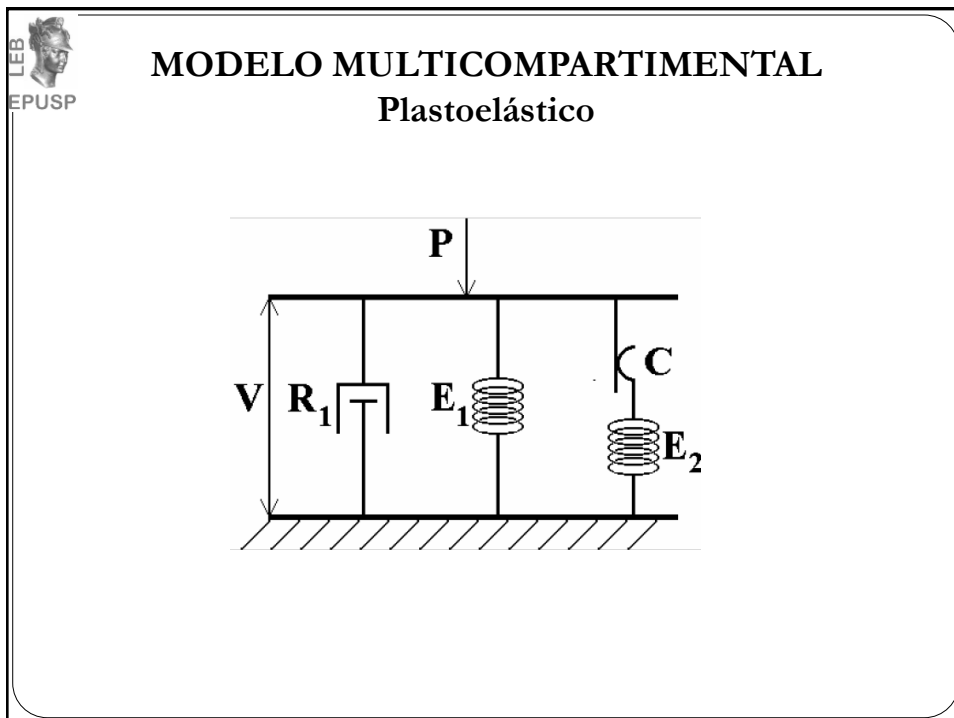
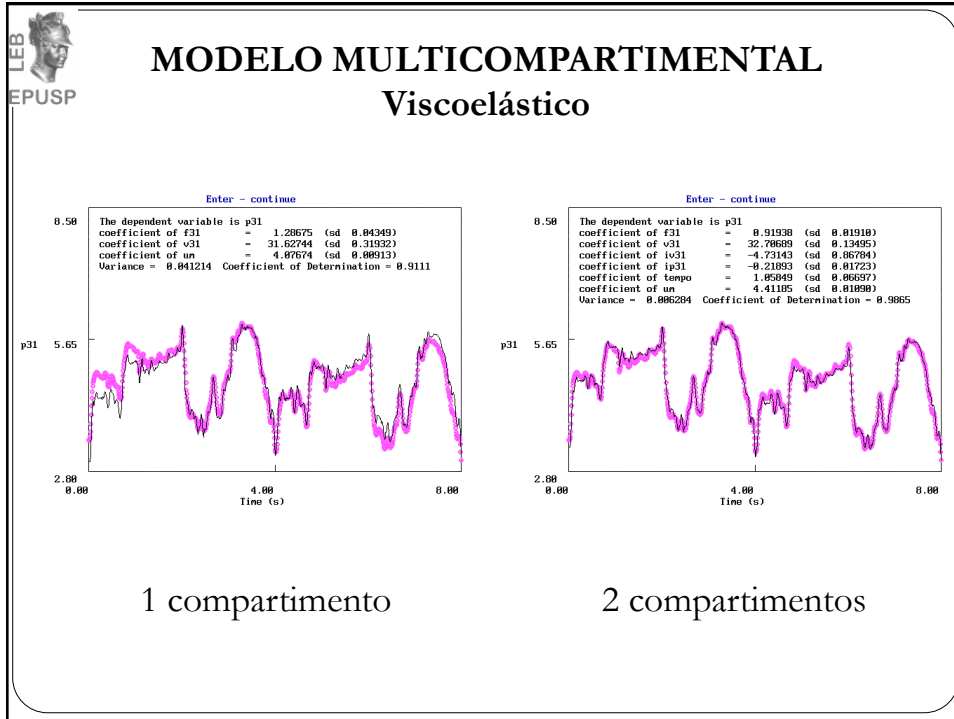












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MODELO MULTICOMPARTIMENTAL

Hildebradt

$$\frac{P_D(t)}{V_D(t)} = A - B \cdot \ln t$$

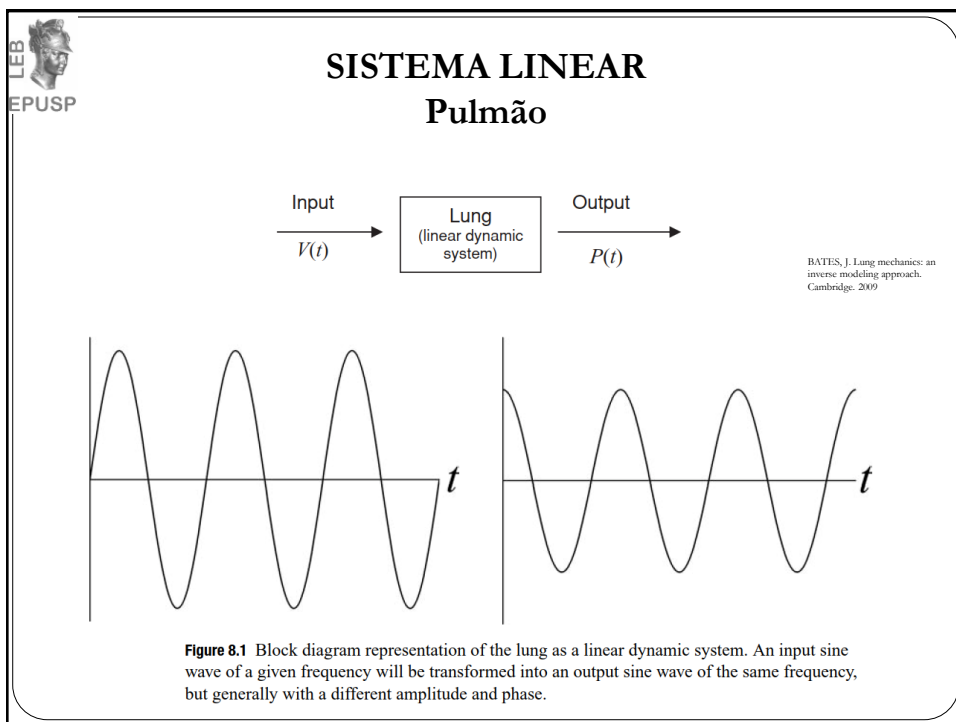
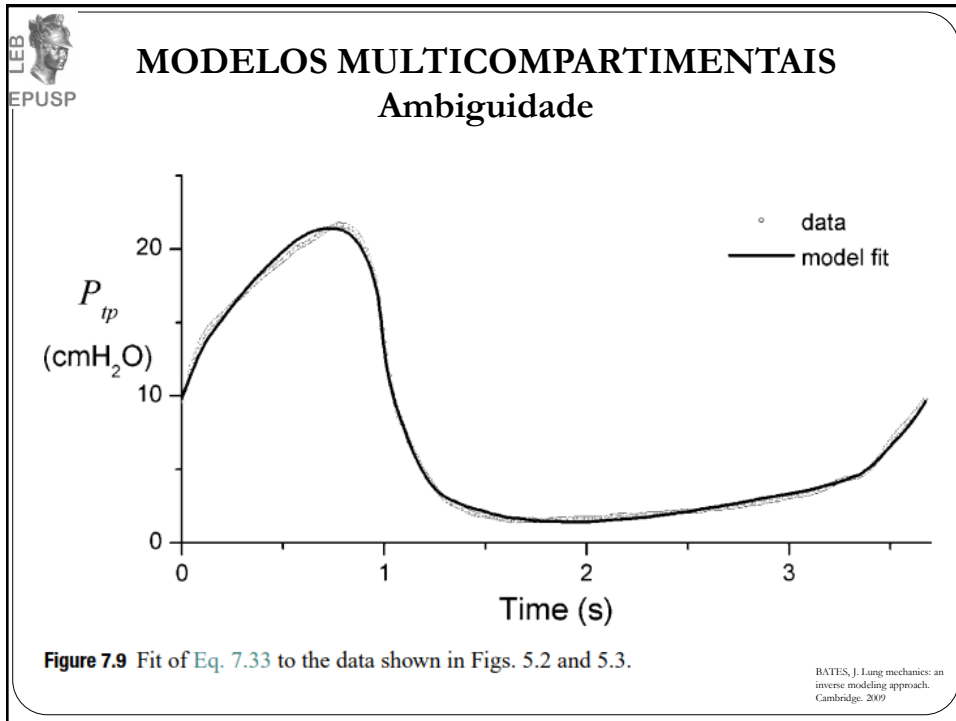
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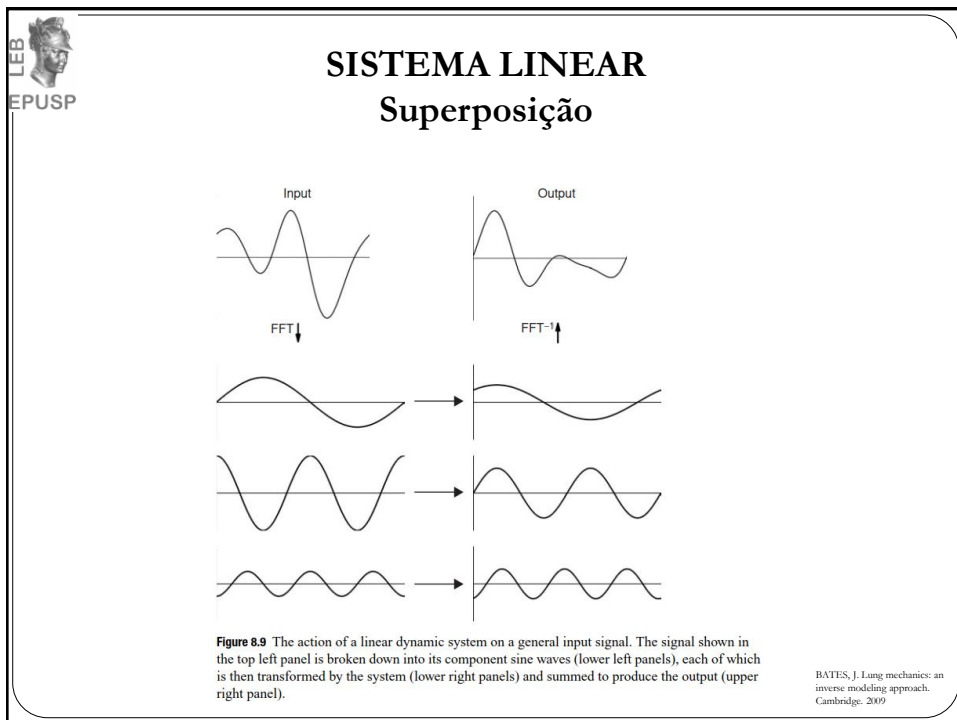
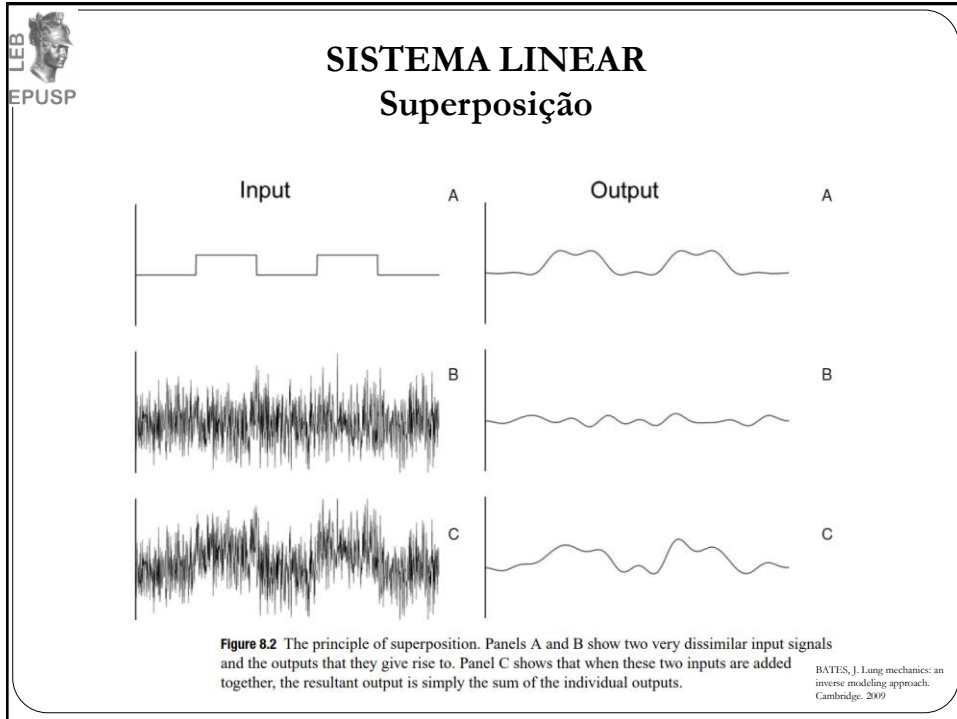
MODELOS MULTICOMPARTIMENTAIS

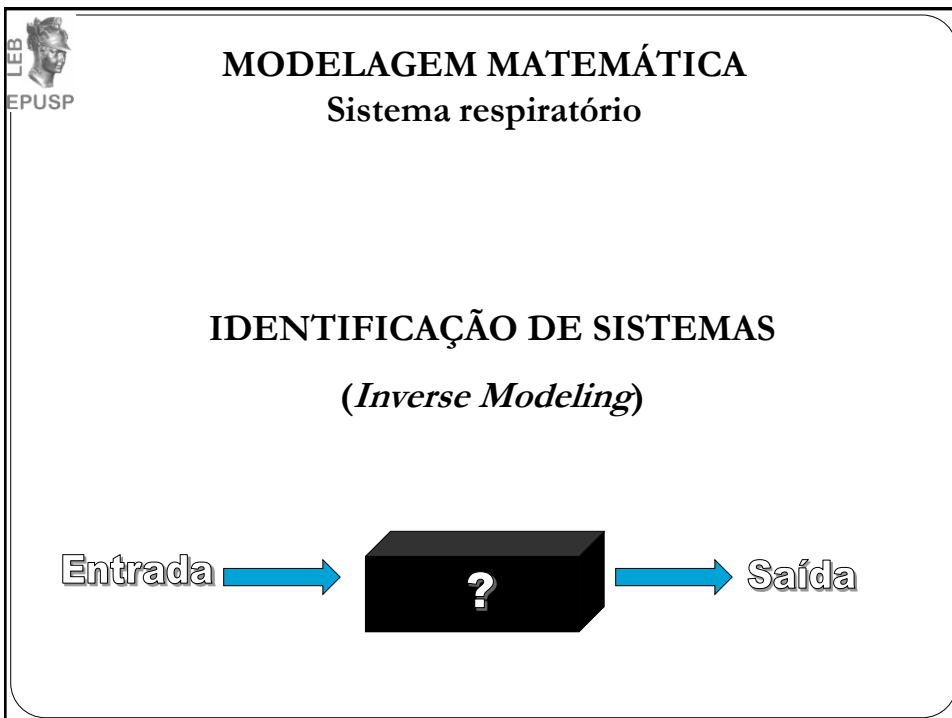
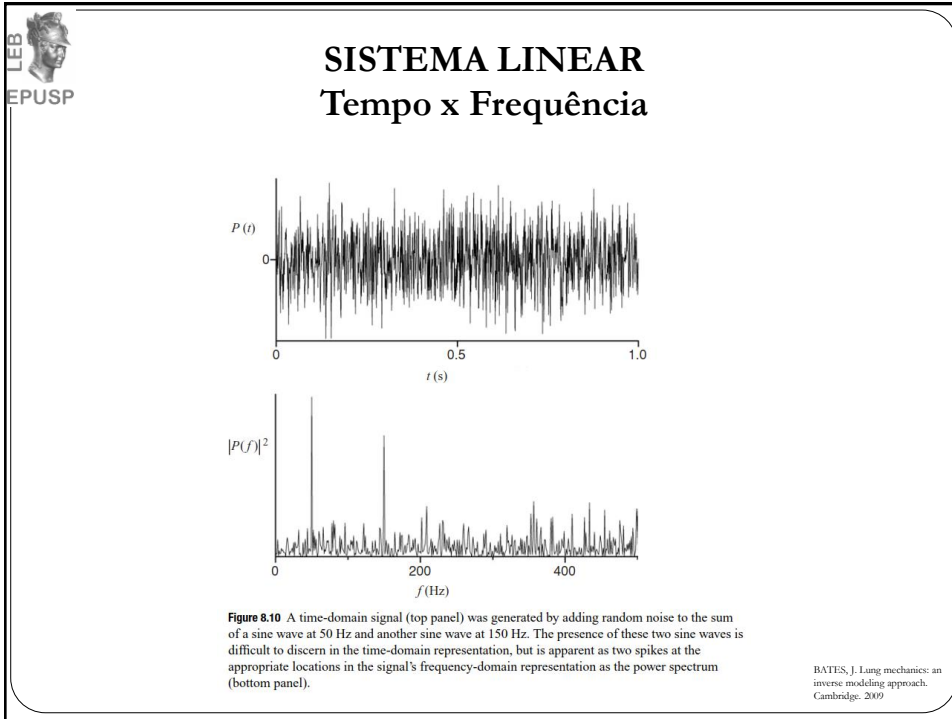
Ambiguidade

Figure 7.7 Schematic representation of airway opening pressure when flow is suddenly interrupted during inspiration (dashed vertical line). The subsequent pressure relaxation can be ascribed either to redistribution of flow between the two compartments of the parallel or series model, or to relaxation of stress in the spring of a Maxwell body via sliding of its associated dashpot.

BATES, J. Lung mechanics: an inverse modeling approach. Cambridge, 2009







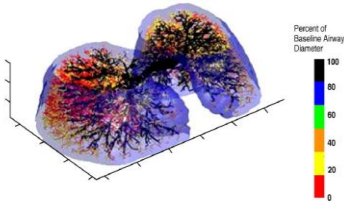
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EPUSP

MODELAGEM MATEMÁTICA

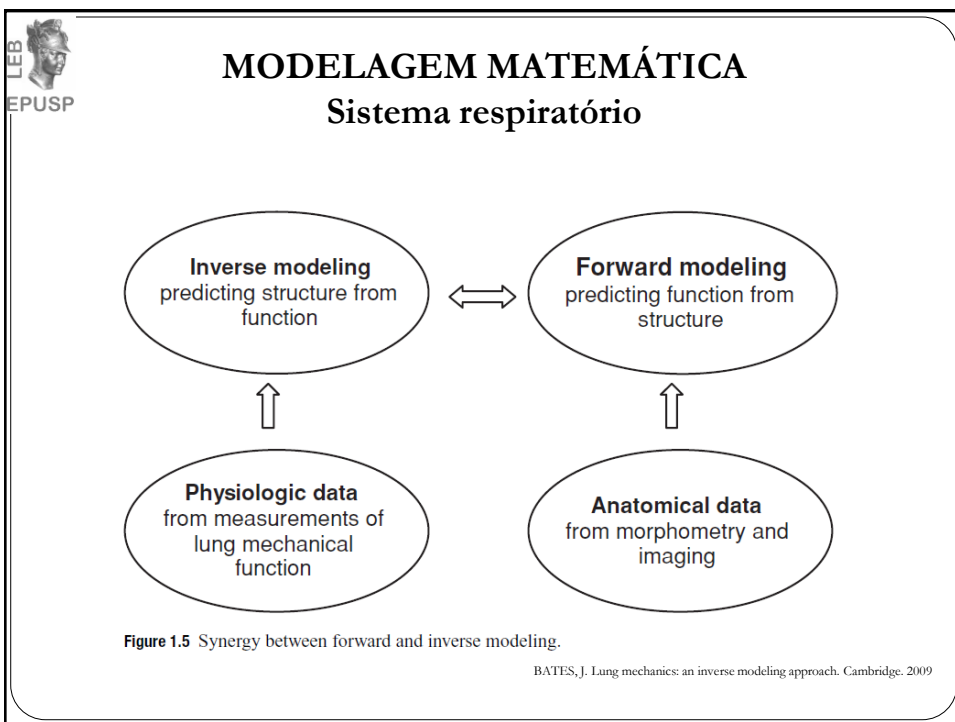
Sistema respiratório

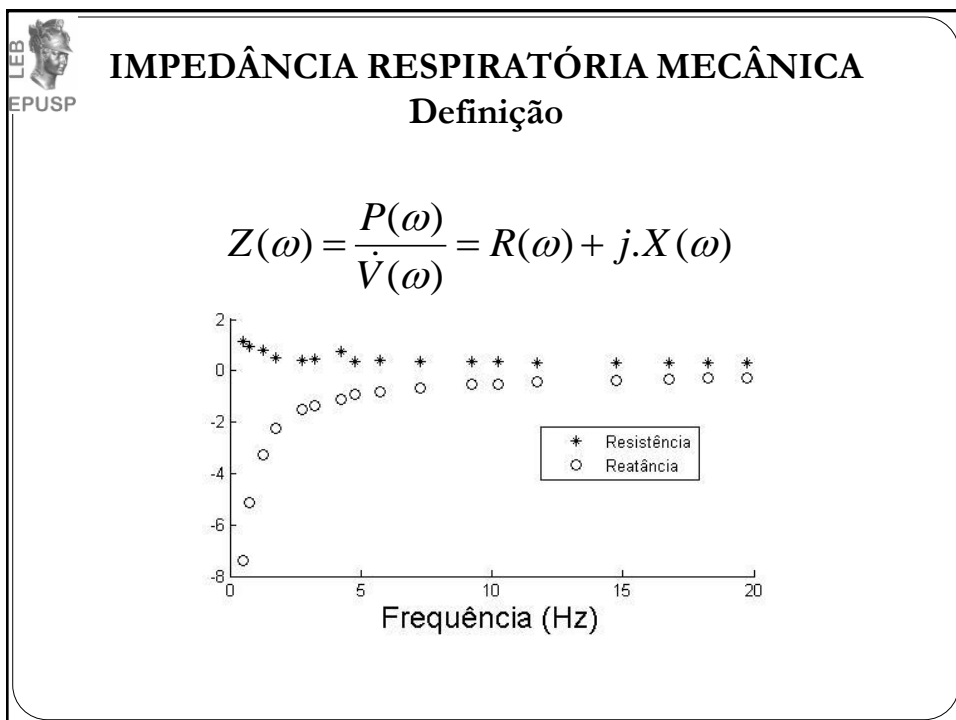
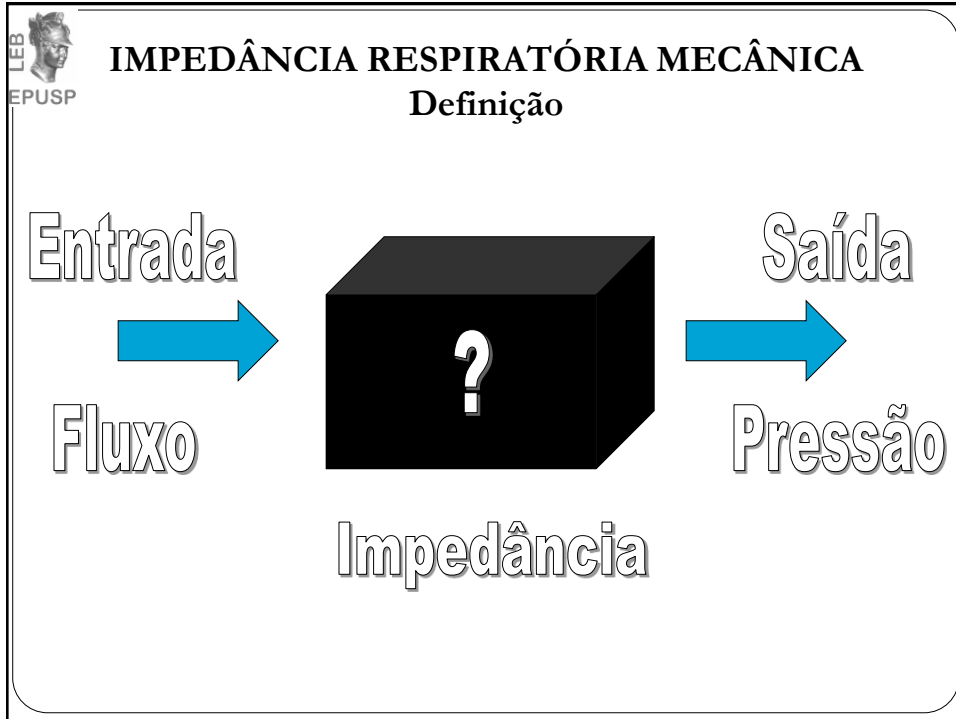
SIMULAÇÃO DE SISTEMAS

(Forward Modeling)



J.H.T. Bates, K.R. Latchen / Respiratory Physiology & Neurobiology 148 (2005) 153–164





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EPUSP

IMPEDÂNCIA RESPIRATÓRIA MECÂNICA De entrada

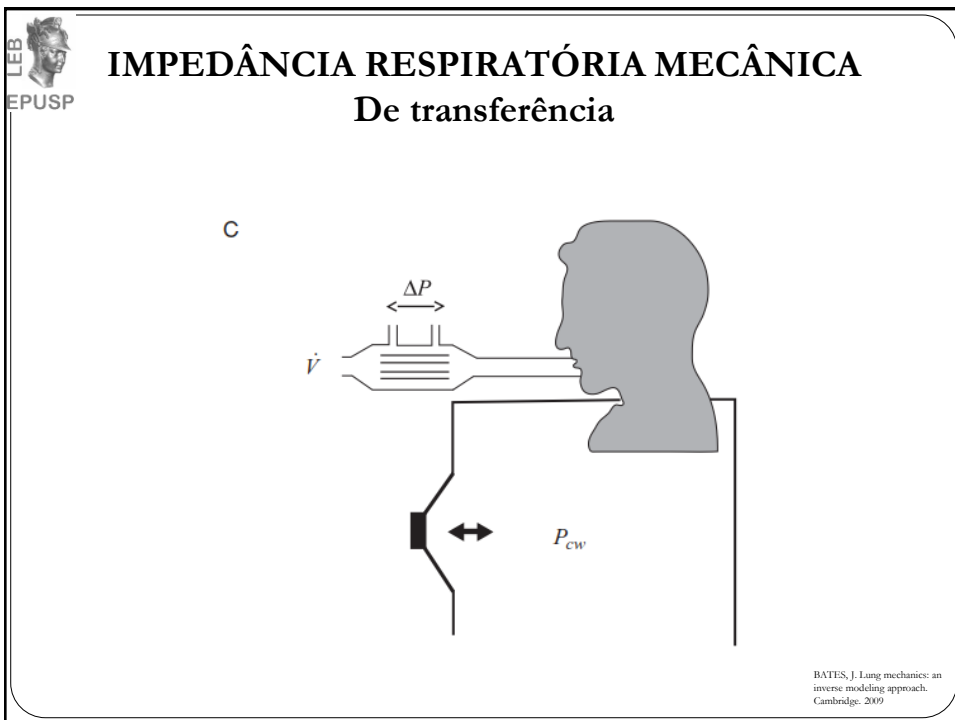
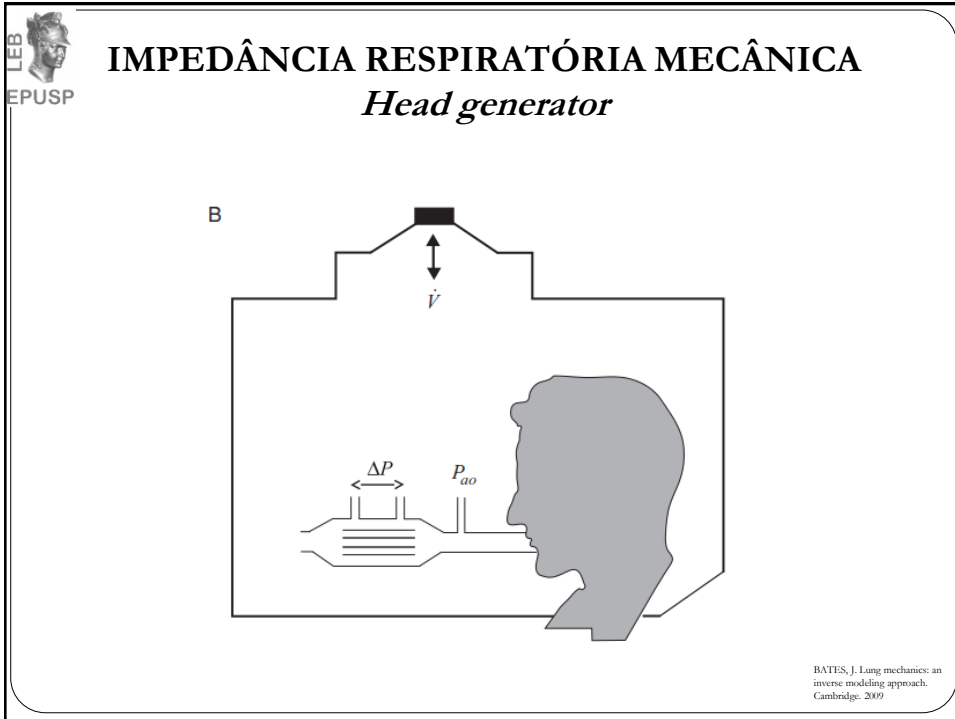
A

$$Z(\omega) = \frac{P(\omega)}{\dot{V}(\omega)}$$

BATES, J. Lung mechanics: an inverse modeling approach. Cambridge, 2009

LEB
EPUSP

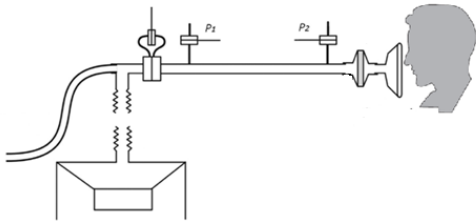
IMPEDÂNCIA RESPIRATÓRIA MECÂNICA De entrada



LEB
EPUSP

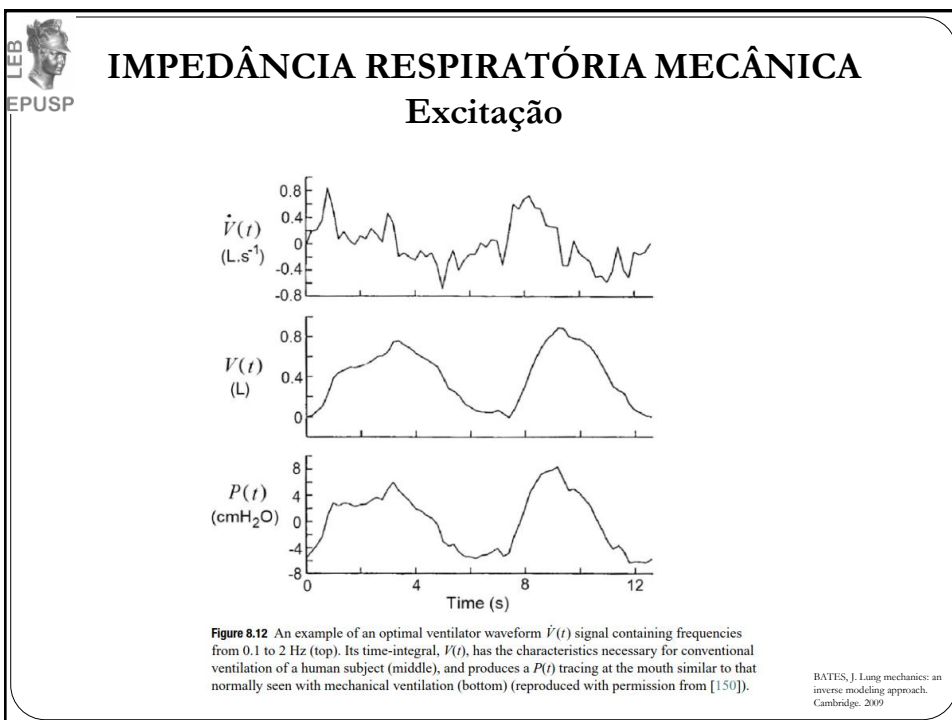
IMPEDÂNCIA RESPIRATÓRIA MECÂNICA

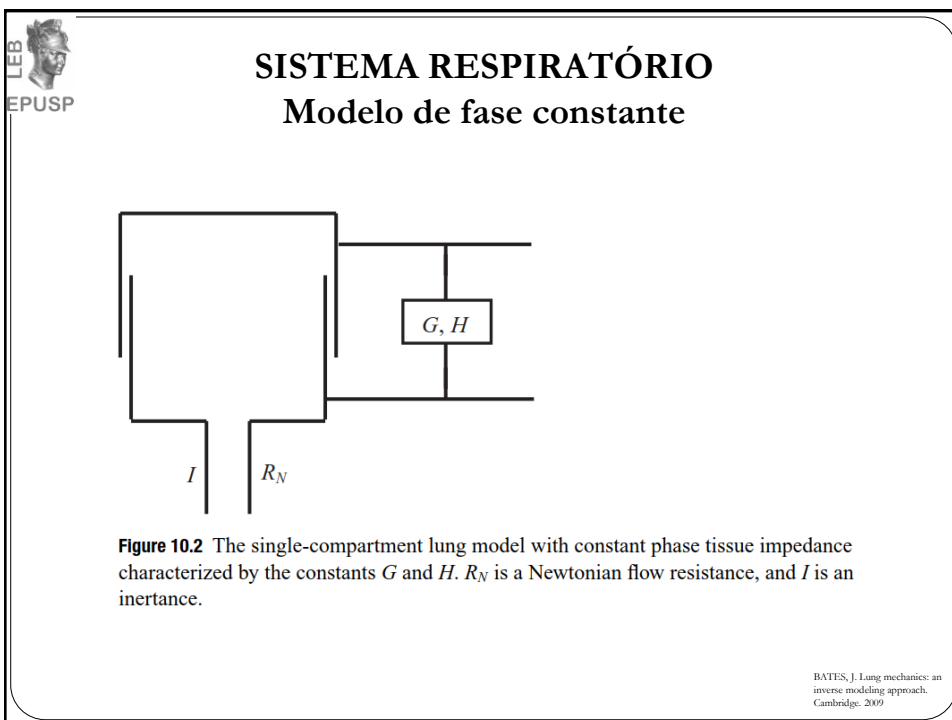
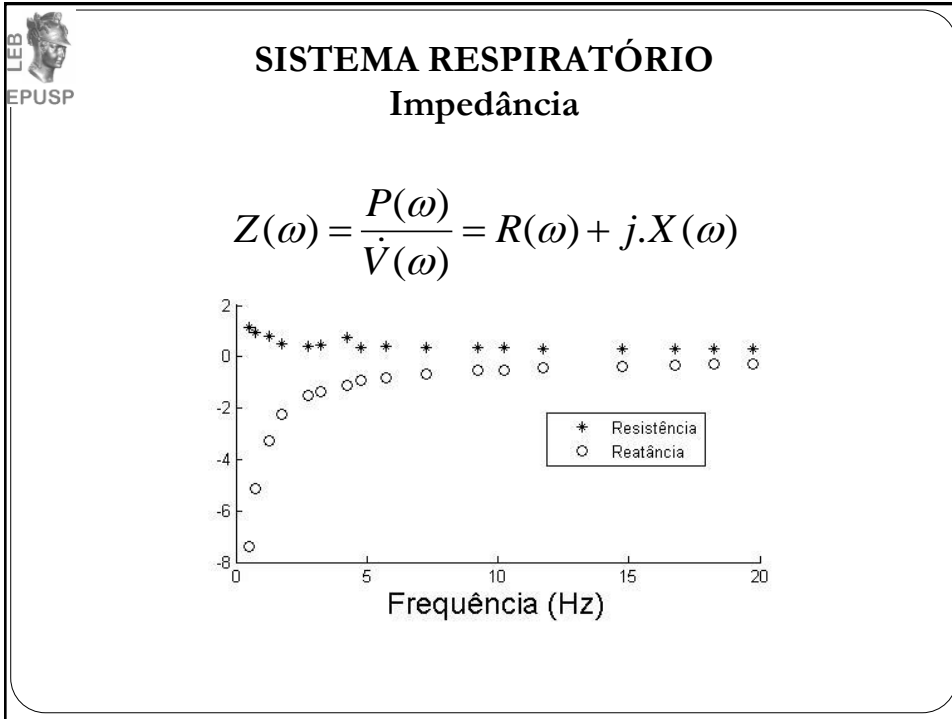
Wavetube



$$Z_L = \frac{Z_0 \sinh(\gamma_0 L)}{\frac{P_1}{P_2} - \cosh(\gamma_0 L)}$$

BATES, J. Lung mechanics: an inverse modeling approach. Cambridge, 2009







SISTEMA RESPIRATÓRIO

Modelo de fase constante

$$Z(f) = R_N + j \cdot \omega \cdot I + \frac{G + j \cdot H}{\omega^\alpha}$$

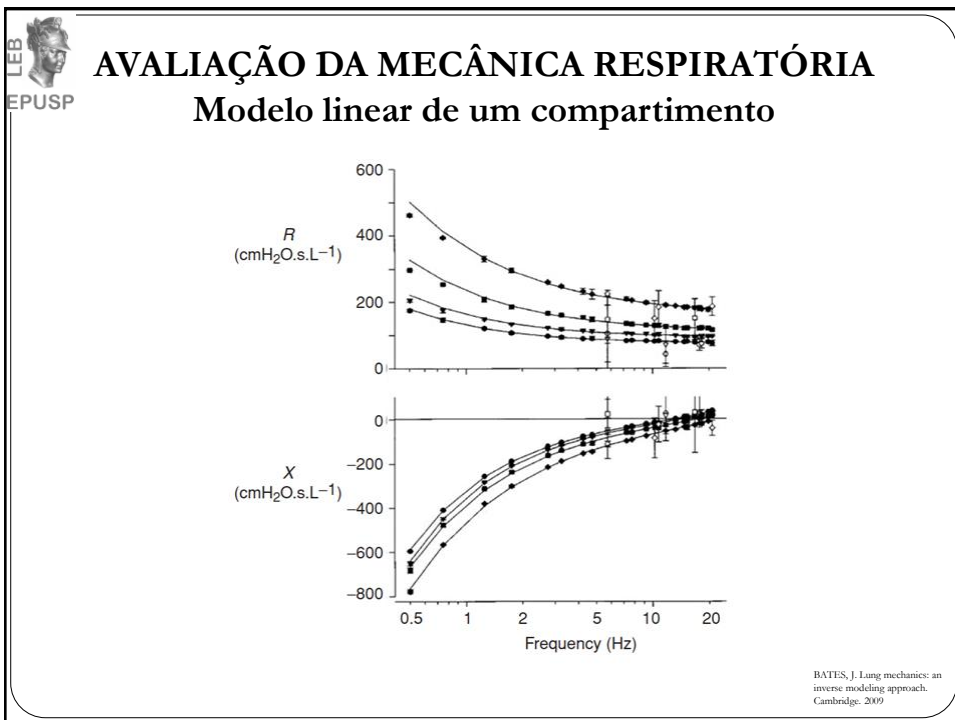
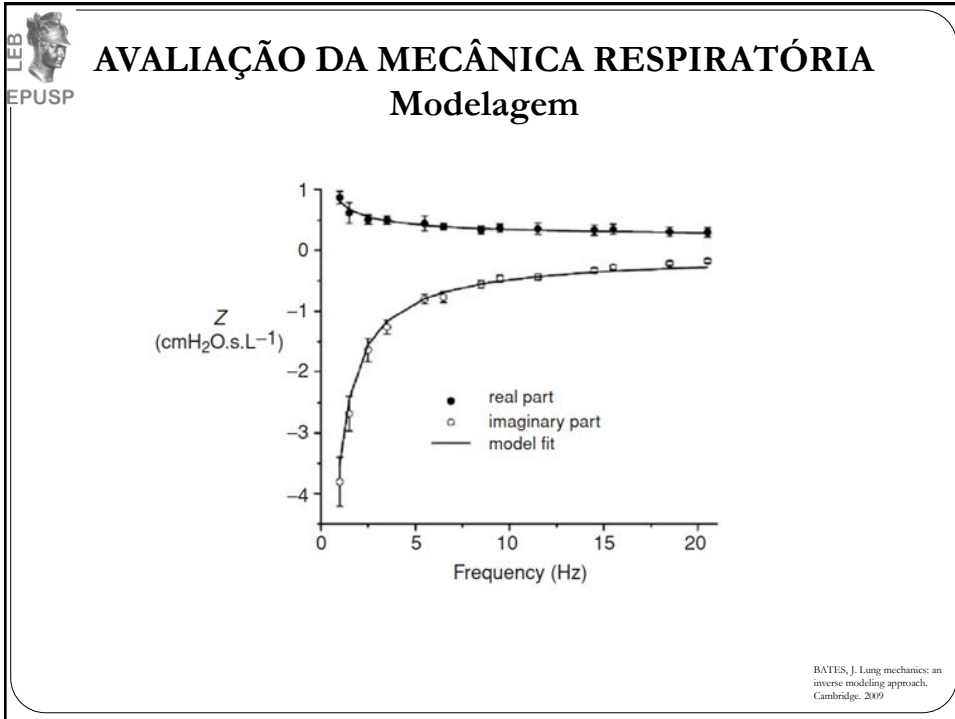


Modelagem em frequência:

modelo de fase constante

$$Z_L = R_{aw} + i \cdot 2 \cdot \pi \cdot f \cdot I_{aw} + \frac{G_{tis} - i \cdot H_{tis}}{(2 \cdot \pi \cdot f)^\alpha}$$

$$\alpha = \frac{2}{\pi} \cdot \tan^{-1} \left(\frac{H_{tis}}{G_{tis}} \right)$$





TAREFA

Capítulo 6

