Anatomie du larynx

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Quelques notions d'orientation…

Gauche/droite

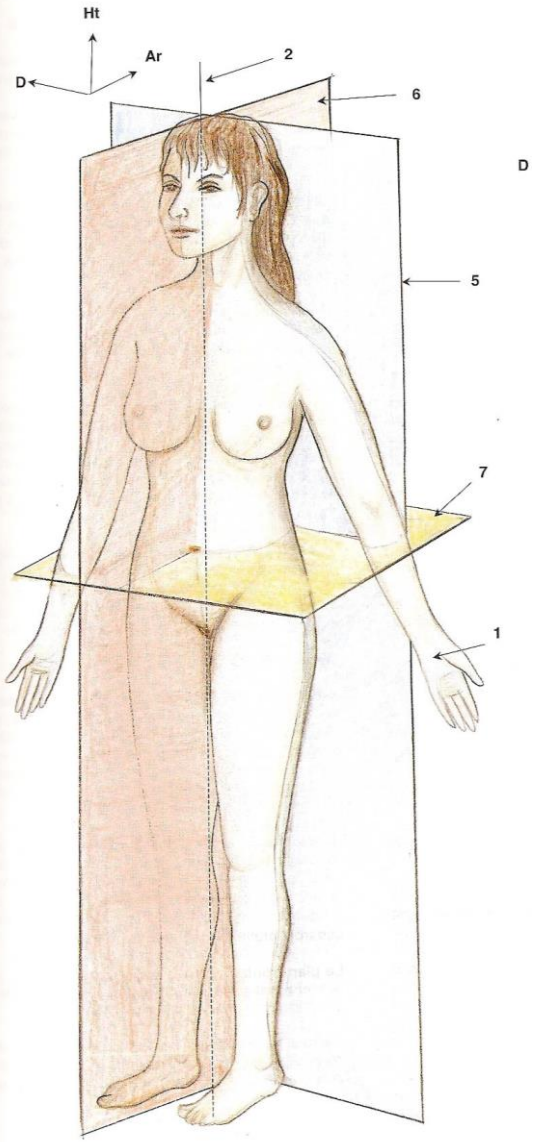
En haut/en bas

Avant/arrière

Plan sagittal = antéro-postérieur

Plan frontal=de gauche à droite

Plan transversal/axial= horizontal



Les 3 plans de l'espace sur un sujet vue de 3/4 gauche, en position anatomique de référence

Pour parler, il faut…

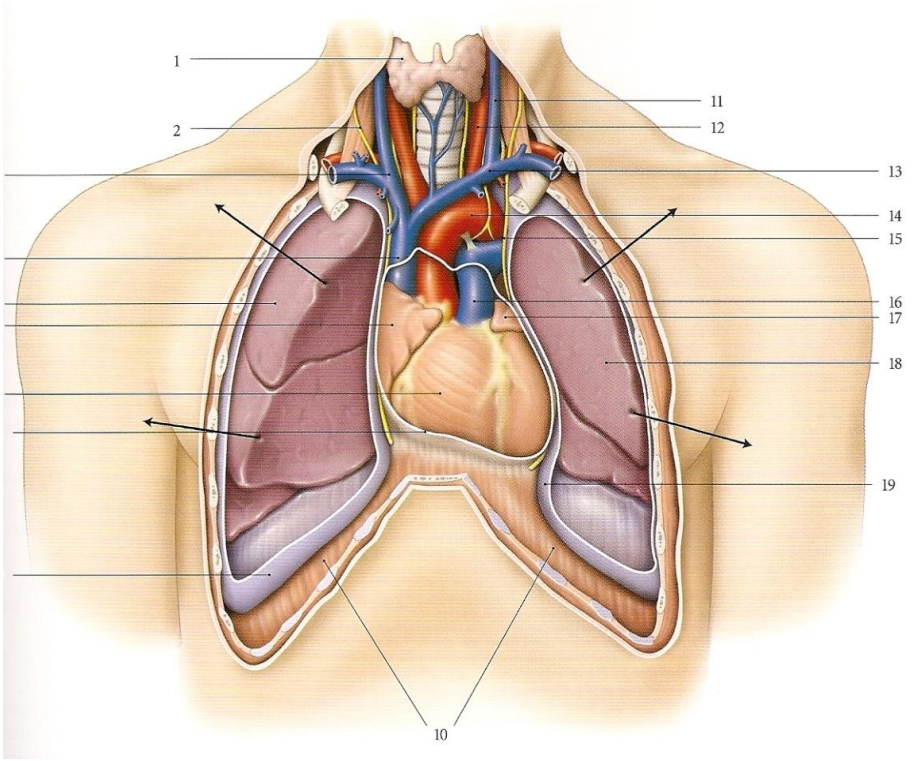
Des résonateurs

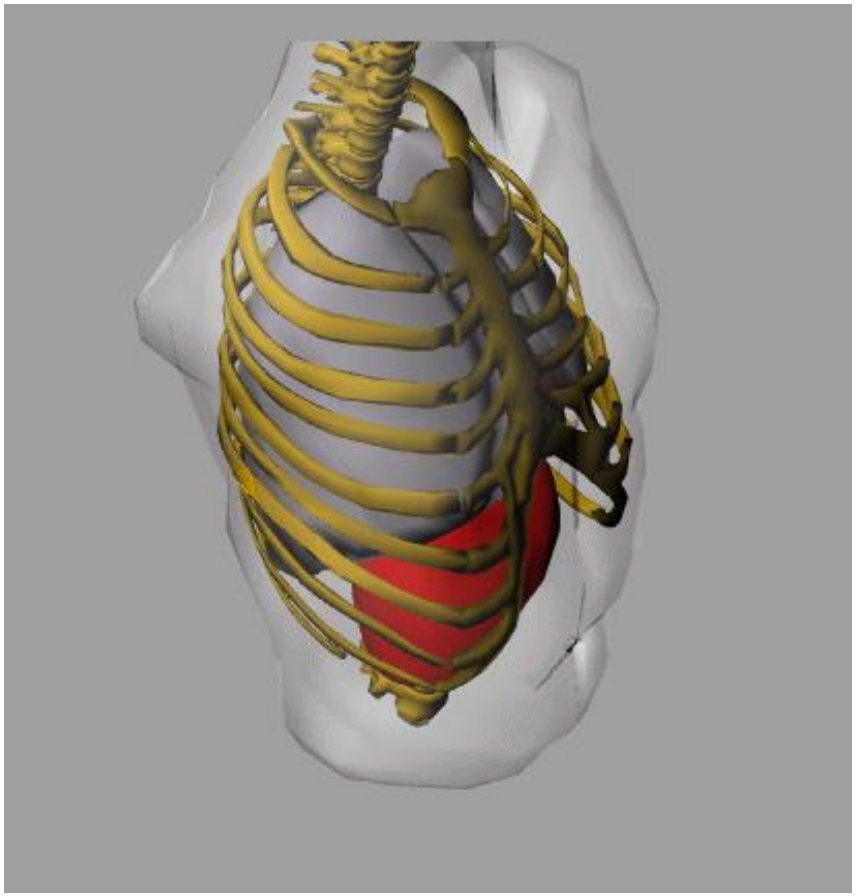
[Des plis vocaux es

De l'air

L’appareil respiratoire

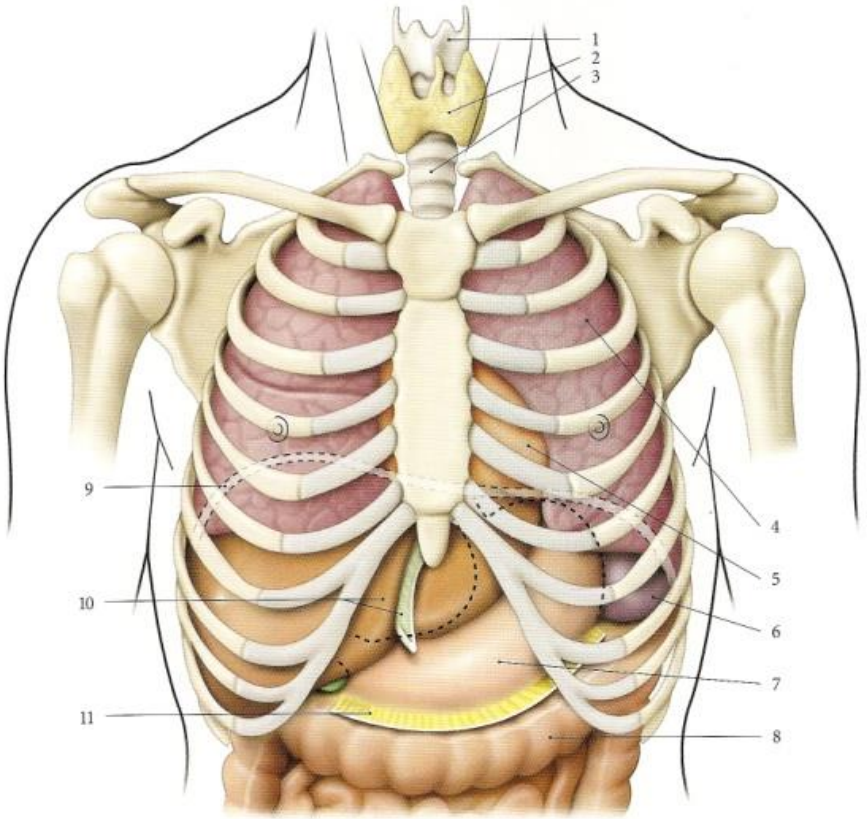
L’appareil respiratoire

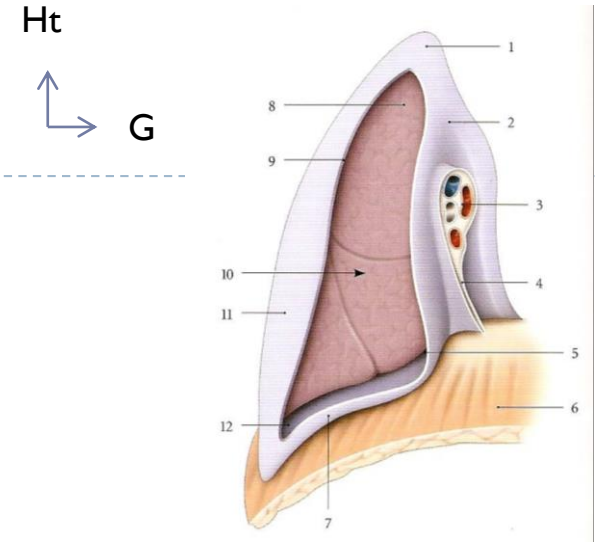


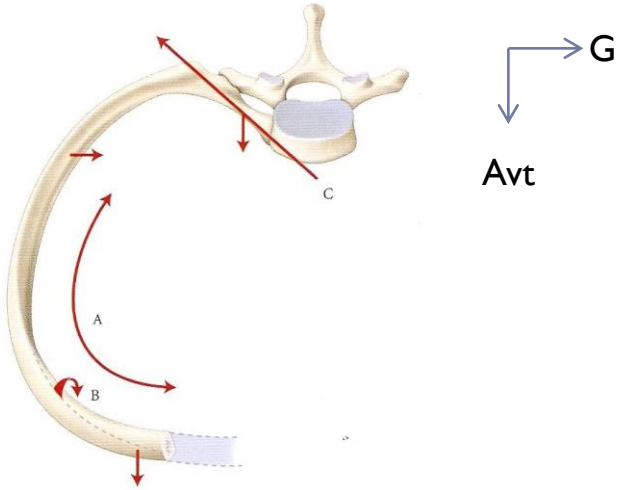


http://belcantoitaliano.blogspot.com

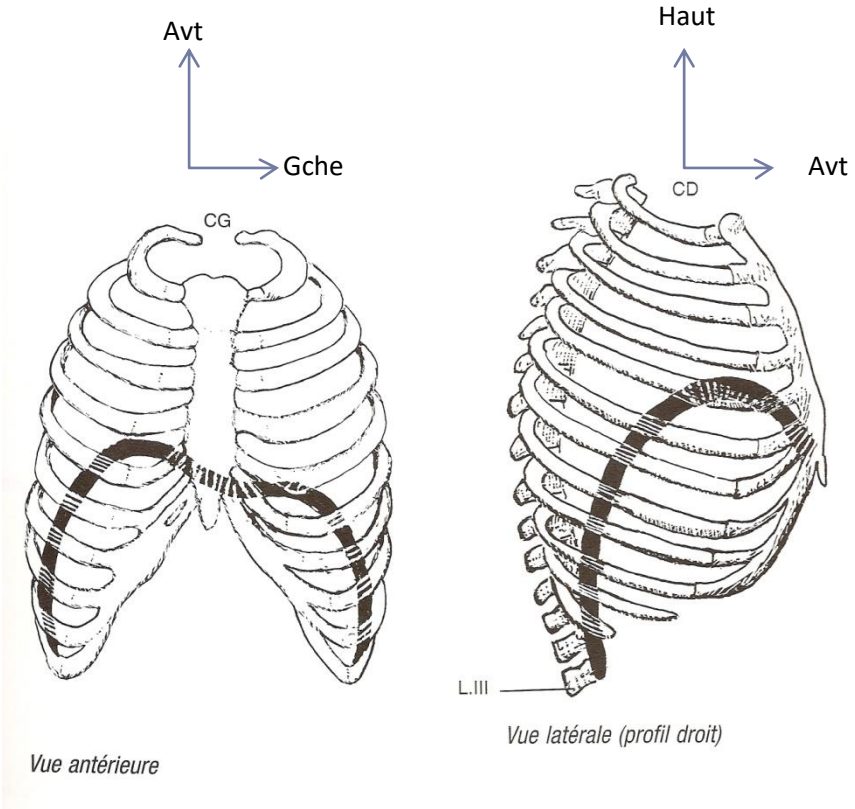
L'appareil respiratoire



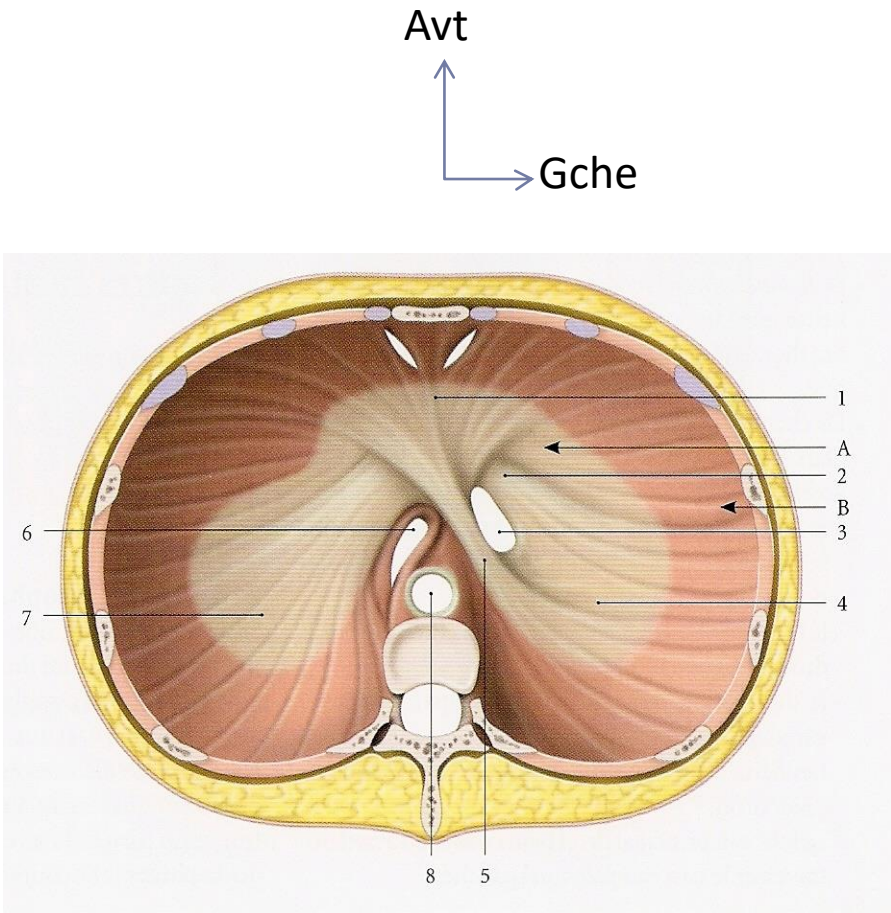




L'appareil respiratoire



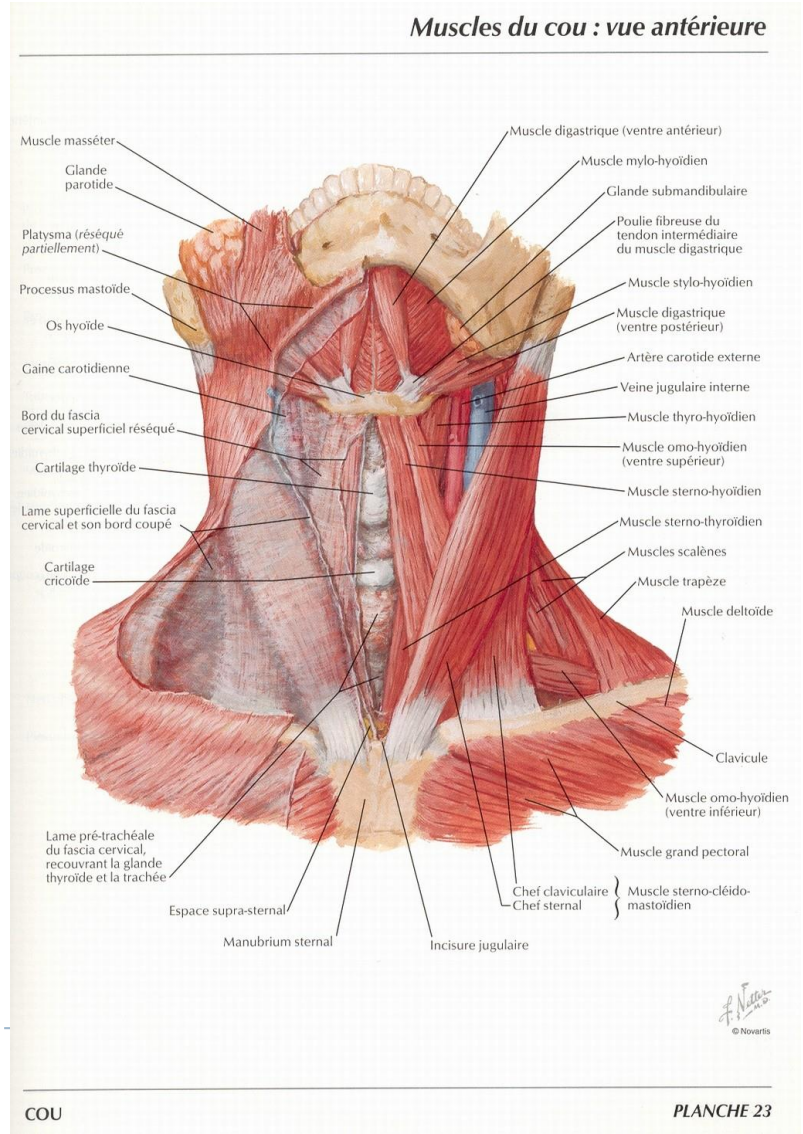
Projection du diaphragme sur la cage thoracique



Vue supérieure du diaphragme

L'appareil respiratoire

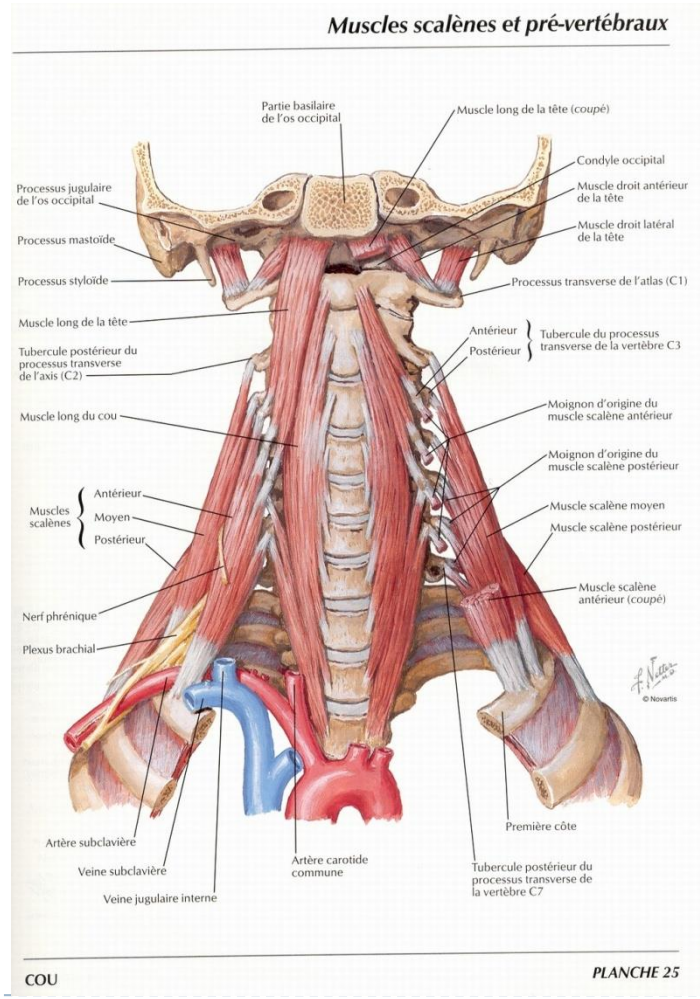
- Muscles inspiratoires accessoires
- Muscles intercostaux externes
- Sterno-cléido-mastoïdien



L'appareil respiratoire

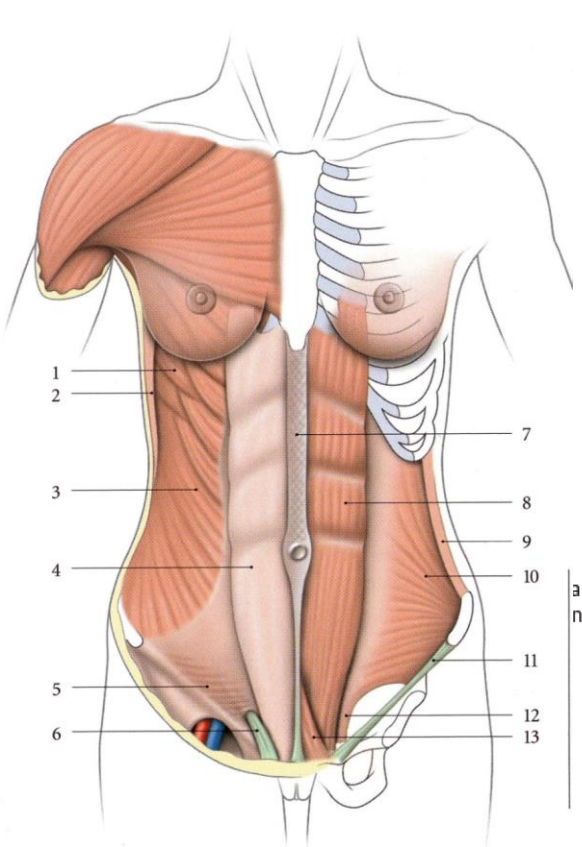
- Muscles inspiratoires accessoires

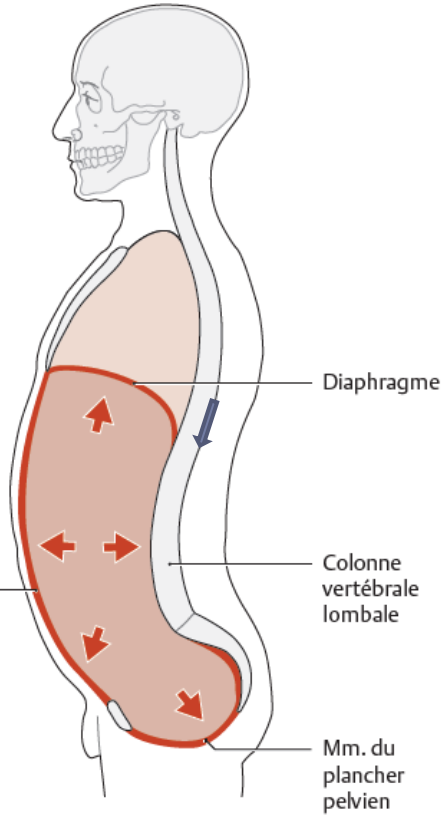
- Muscles scalènes



L'appareil respiratoire

- Expiration passive
- Muscles expiratoires
  - Muscles intercostaux internes
  - Muscles abdominaux



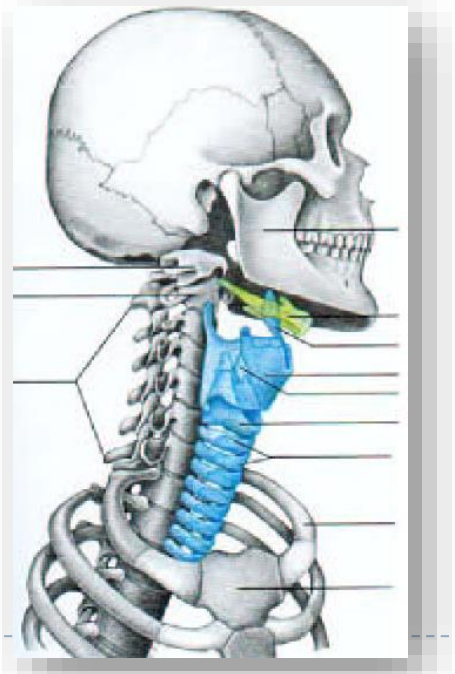


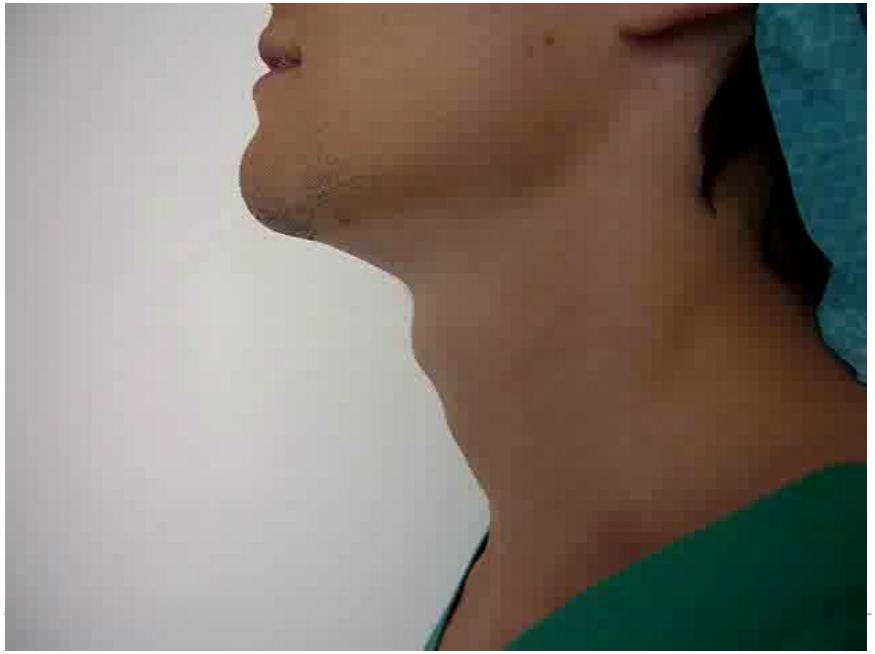
Le larynx

Introduction

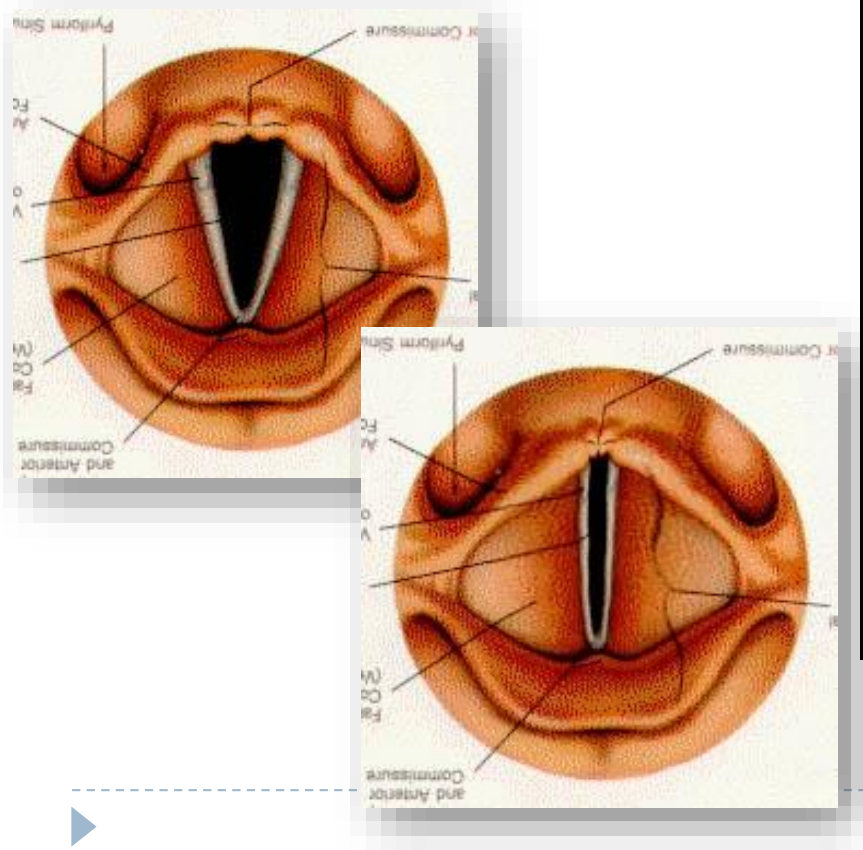
Morphologie externe

- Palpation et morphologie externe

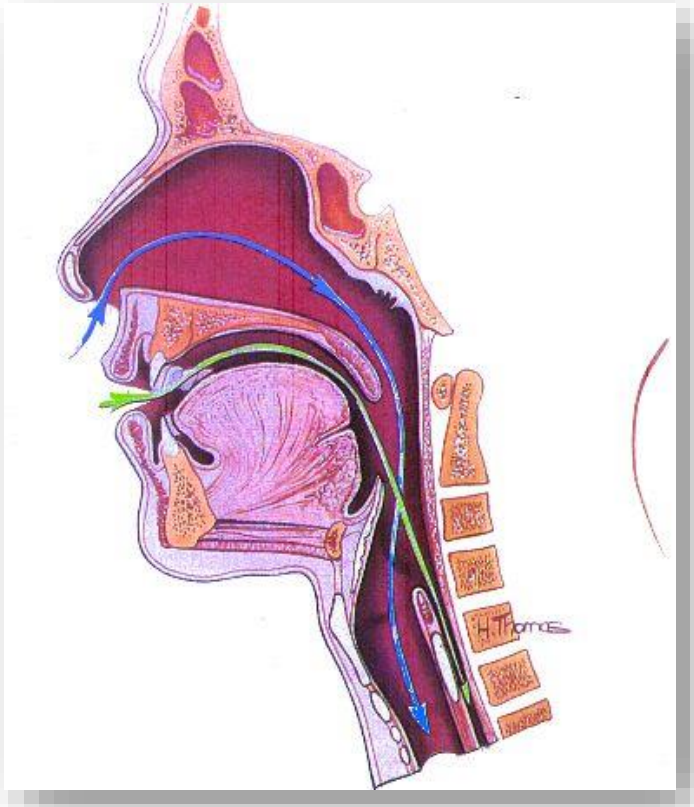




Les fonctions du larynx

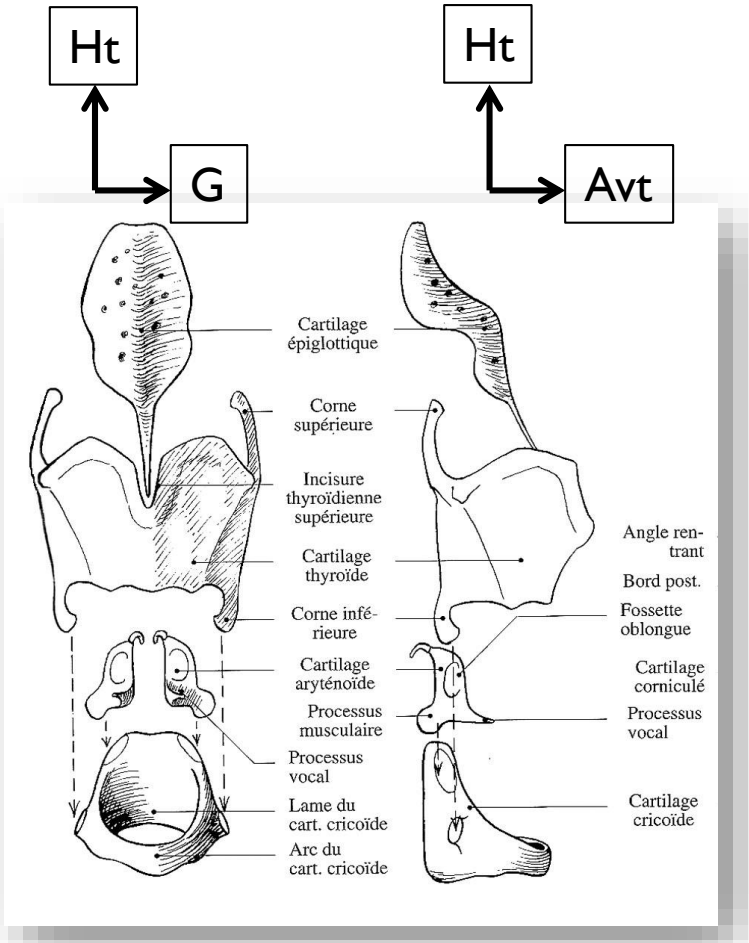


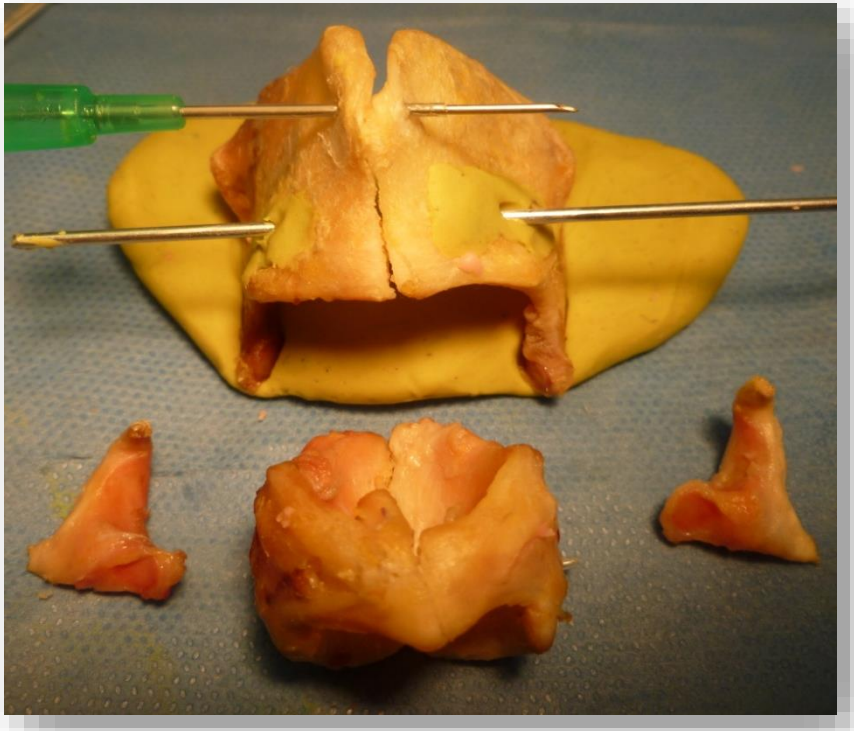
Le carrefour aéro-digestif



Cartilages et articulations

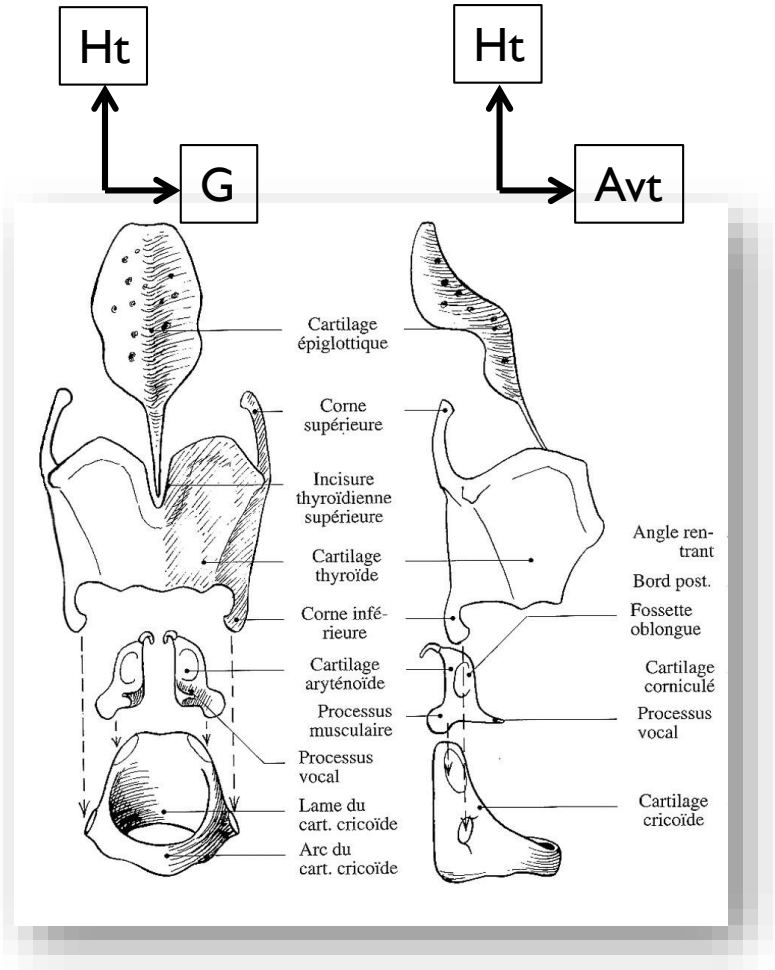
Cartilages et articulations

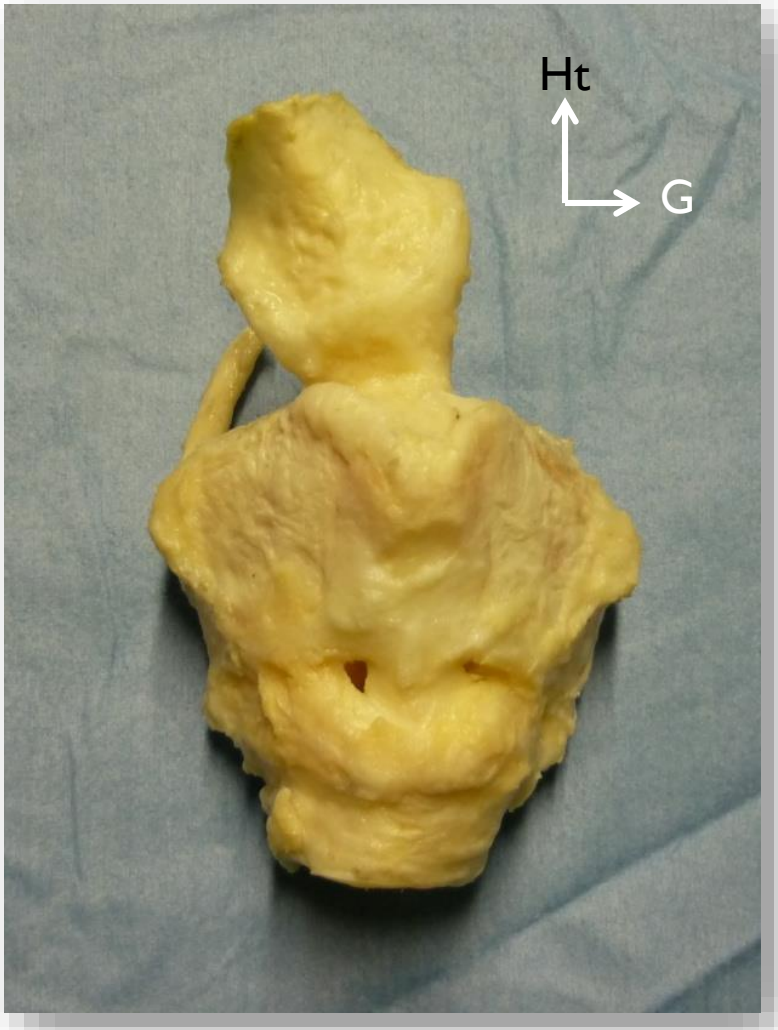




Chevrel JP, Fontaine C. Anatomie clinique, Tome 3, Tête et cou, Ed. Springer, 1996

Cartilages et articulations





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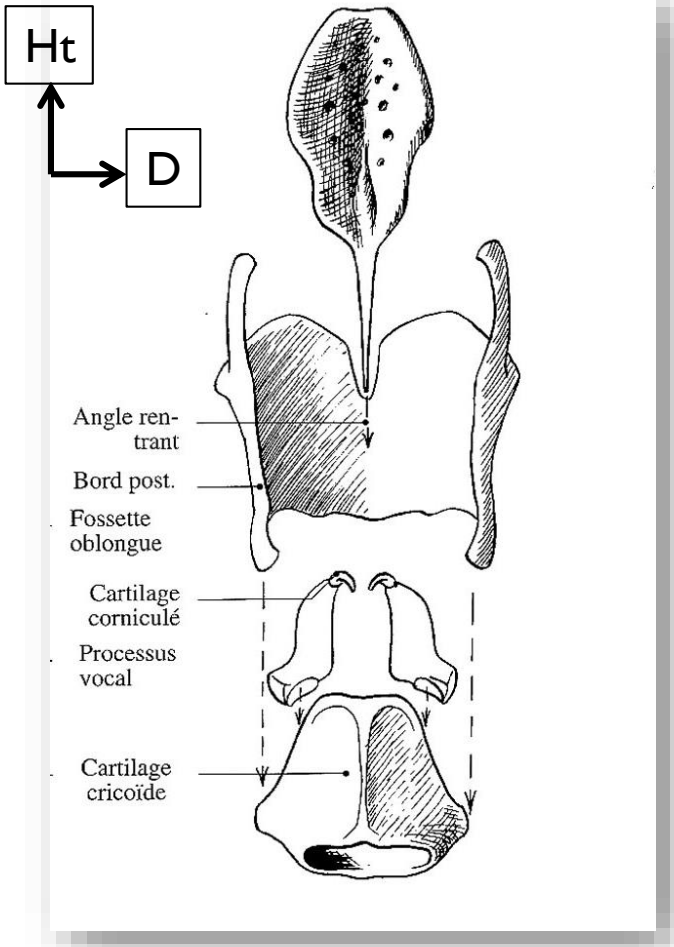
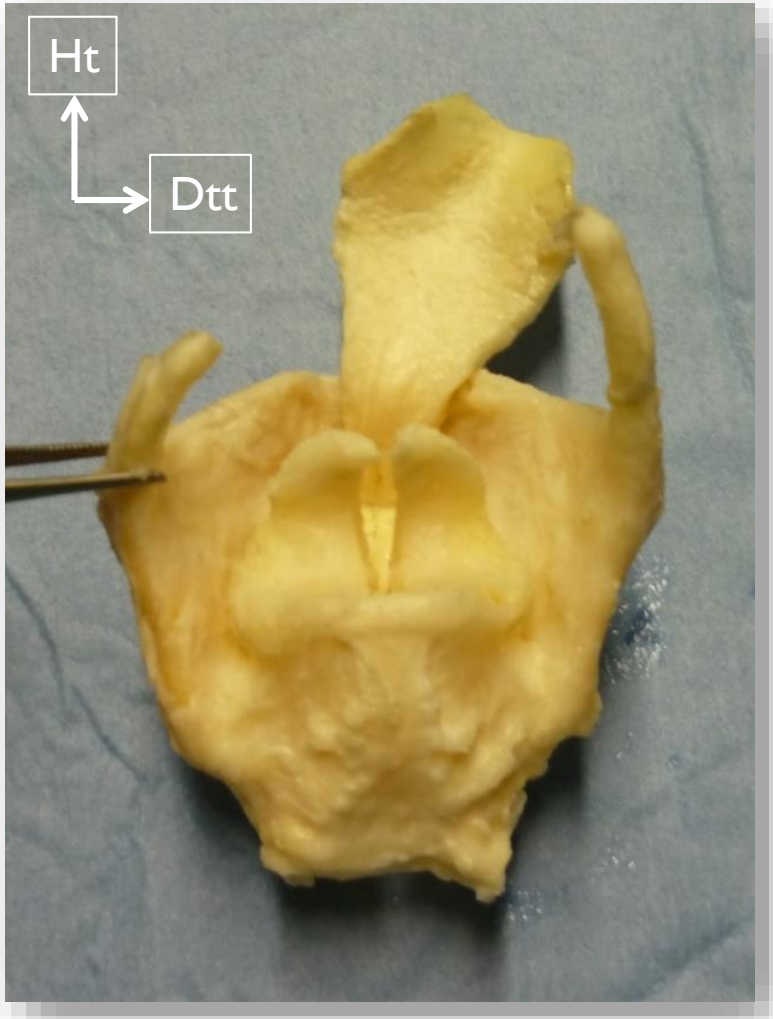
Cartilages et articulations





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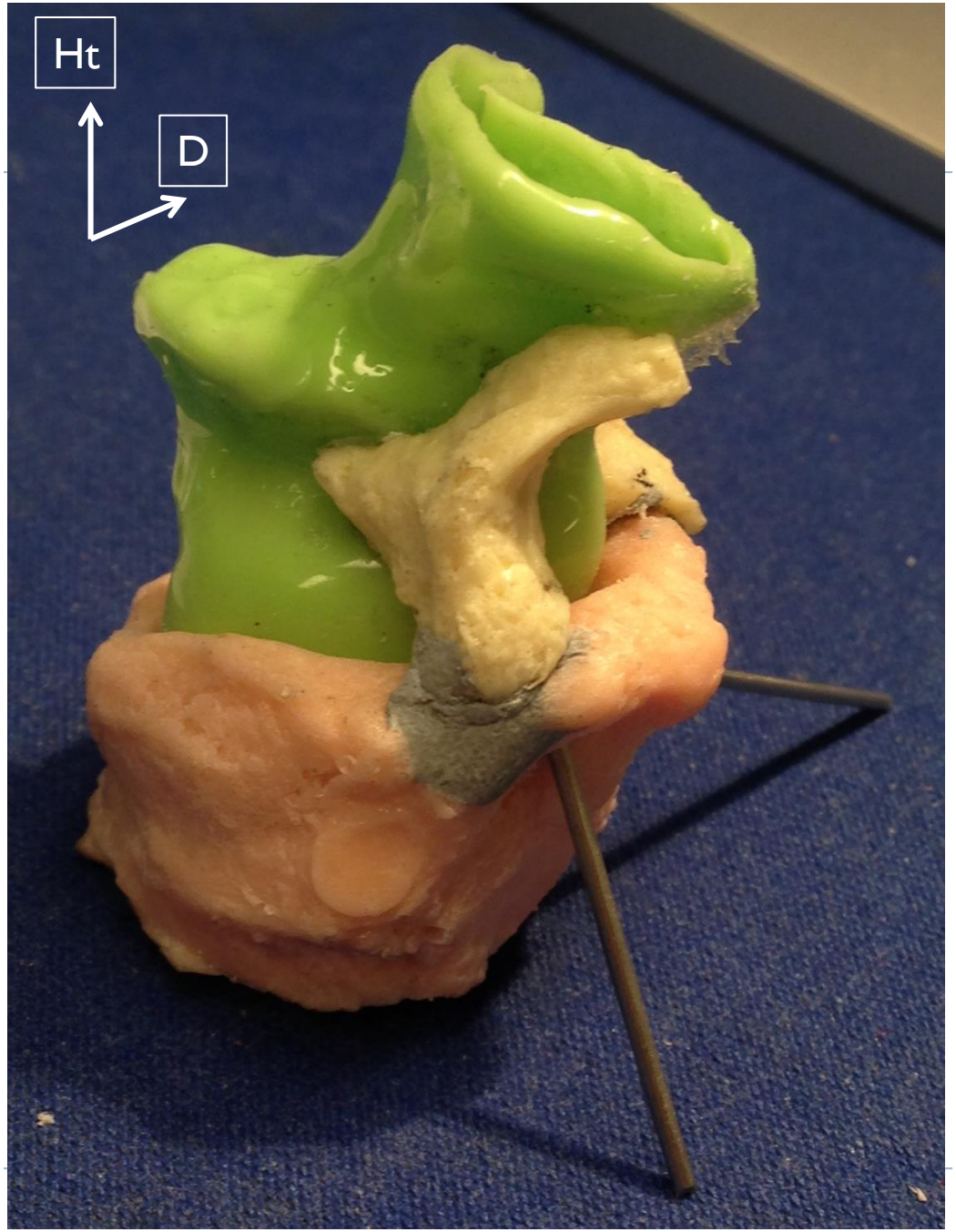
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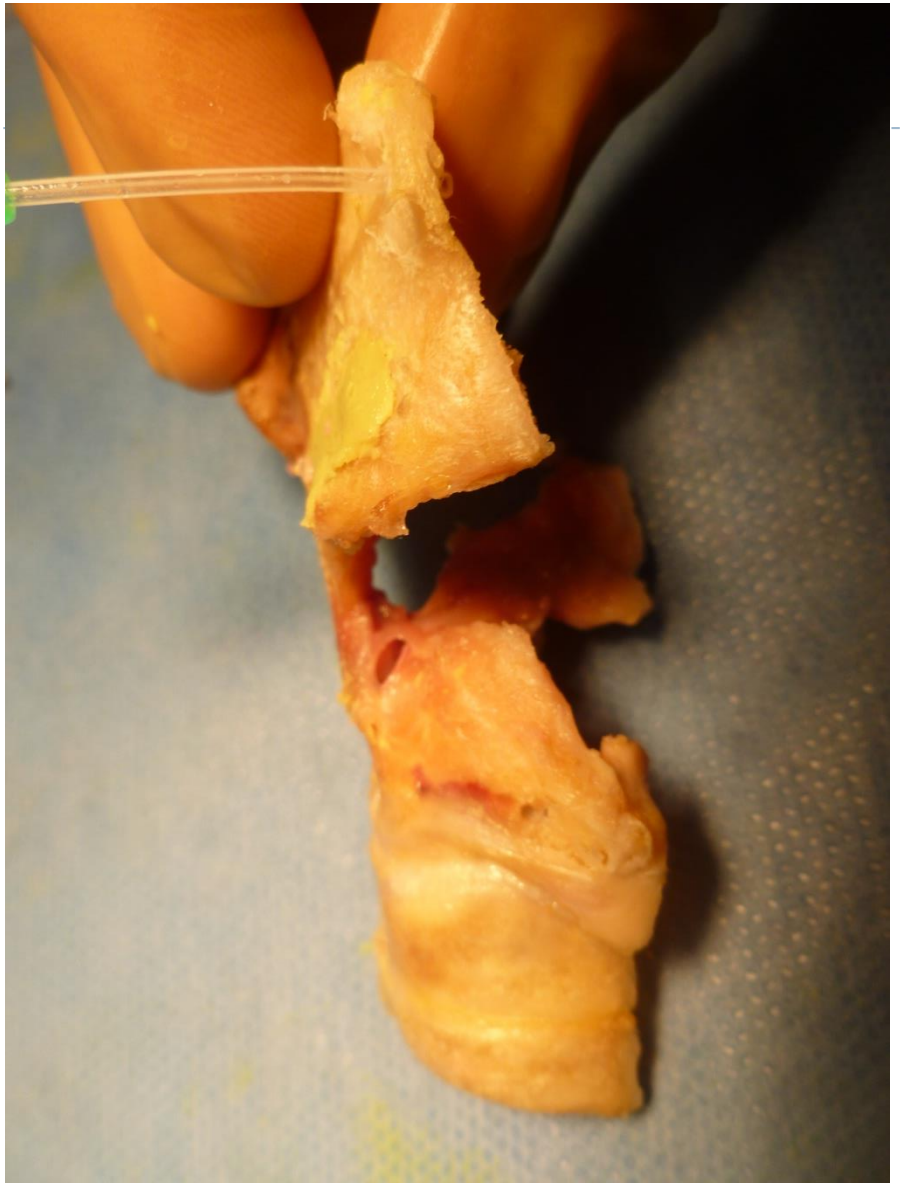
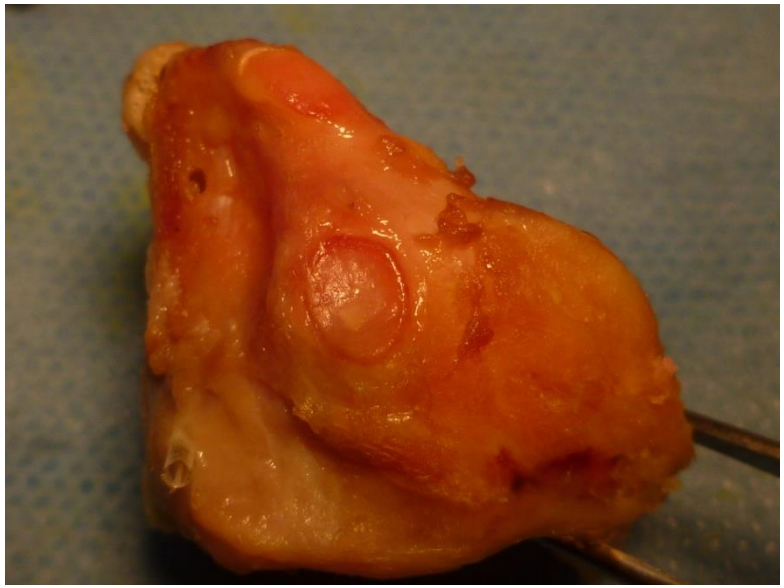
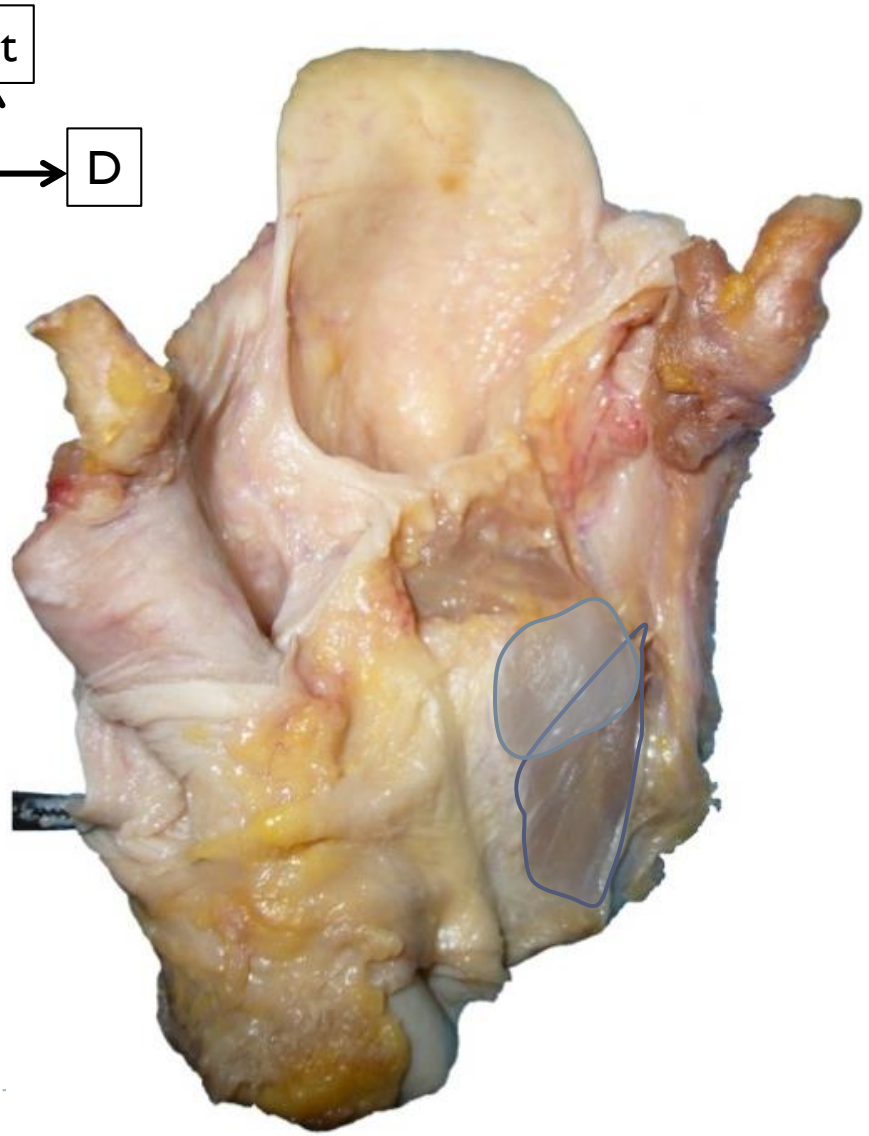




Muscles laryngés intrinsèques

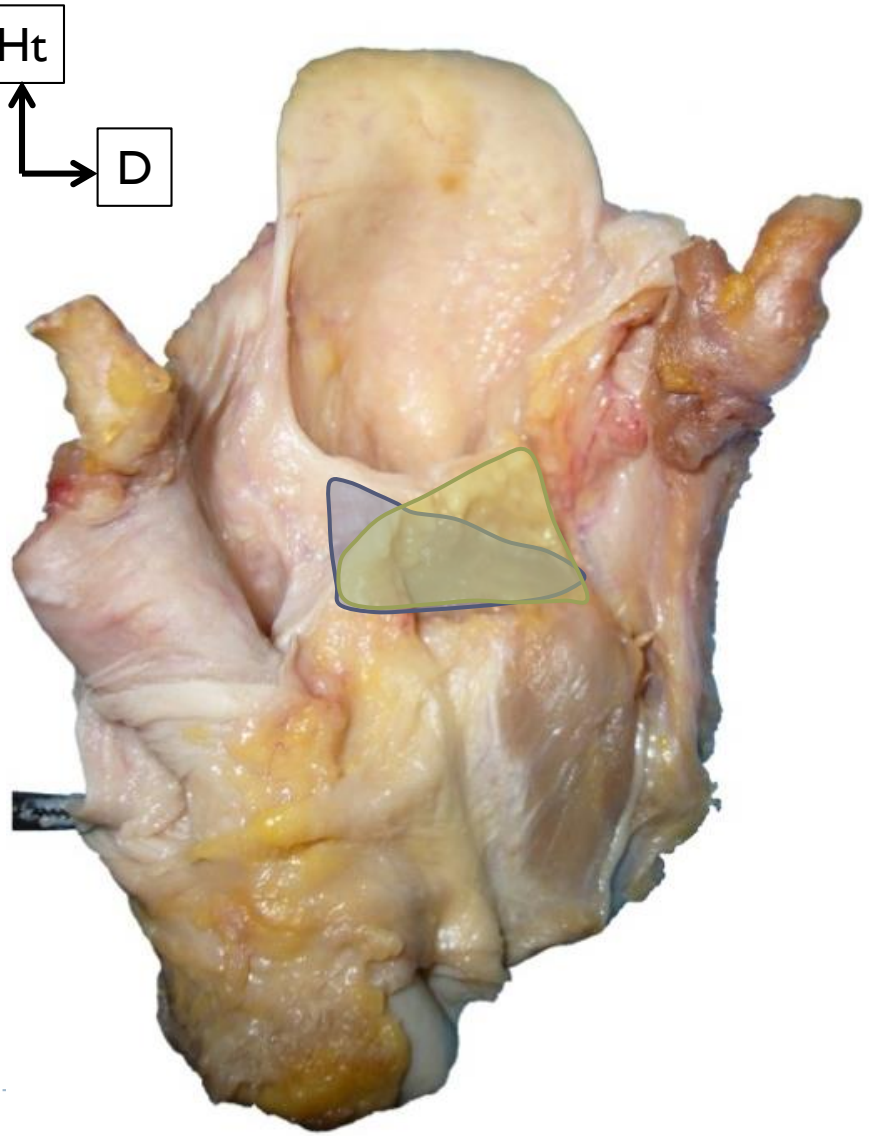
Muscle crico-aryténoïdien postérieur (CAP)

- Abduction des plis vocaux
  - Muscle respiratoire



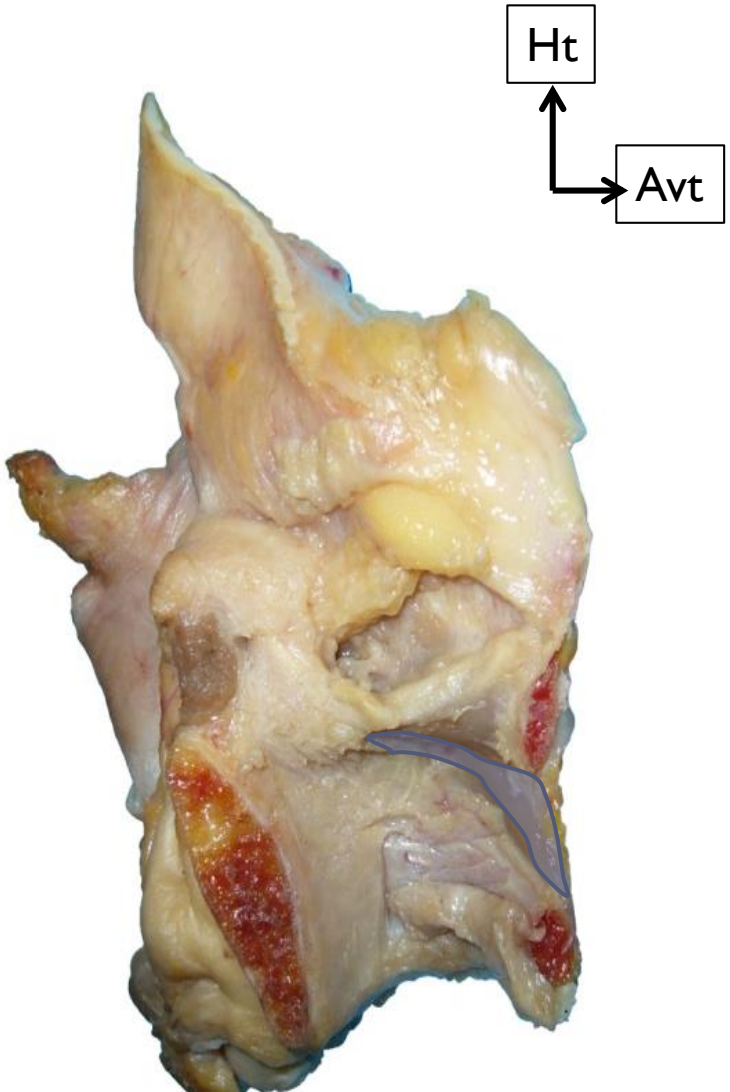
Muscle Inter-aryténoïdien (IA)

- Adduction des aryténoïdes



Muscle crico-aryténoïdien latéral (CAL)

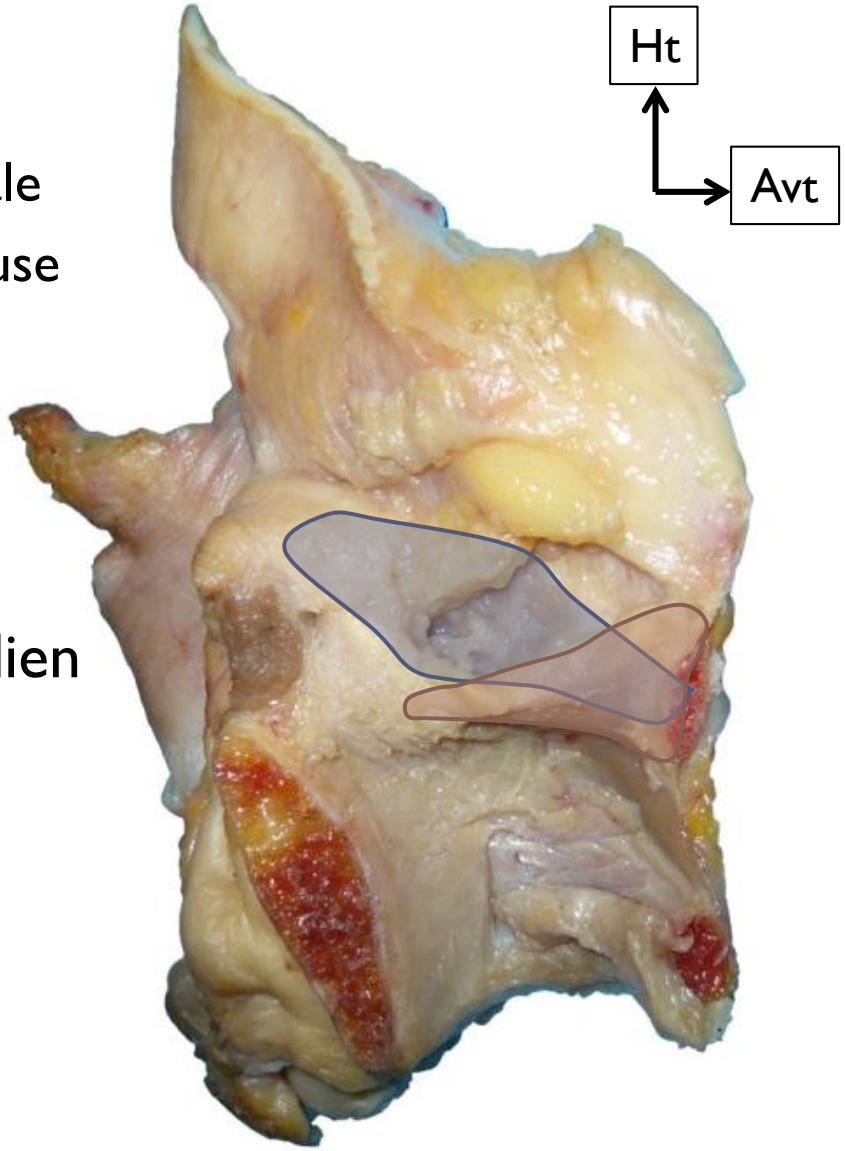
- Adduction du processus vocal de l'aryténoïde
- Elongation du pli vocal



Muscle thyro-aryténoïdien (TA)

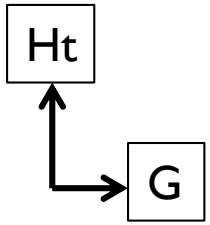
- Adduction du pli vocal
  - Adduction aryténoïdienne marginale
  - Adduction de la partie membraneuse du pli

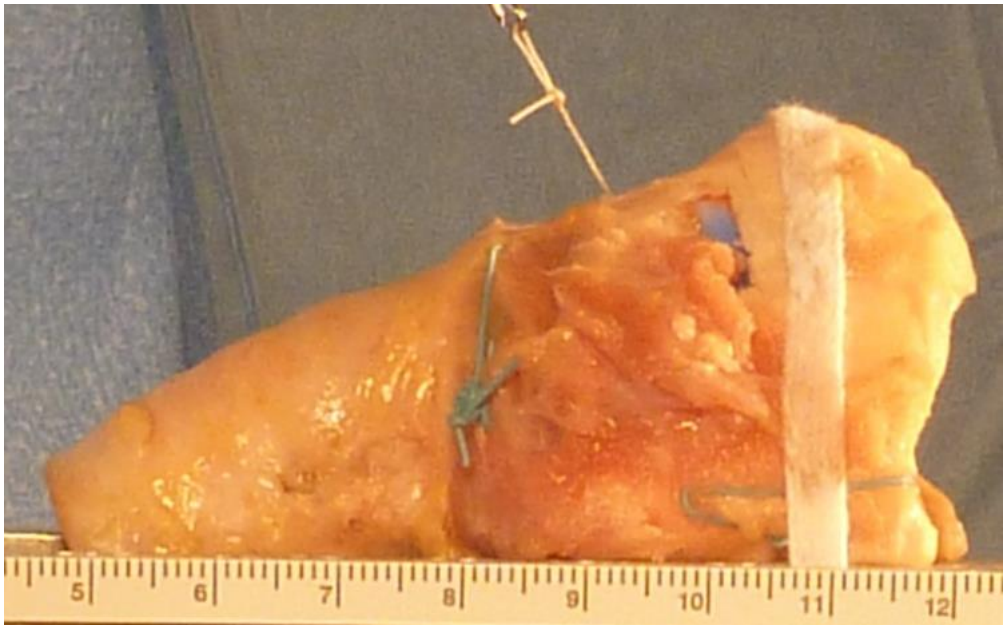
- Rigidification du pli en co-contraction avec le crico-thyroïdien



Muscle crico-thyroïdien

- Elongation des plis
  - Par bascule du cricoïde
- Adduction de la partie membraneuse des plis vocaux

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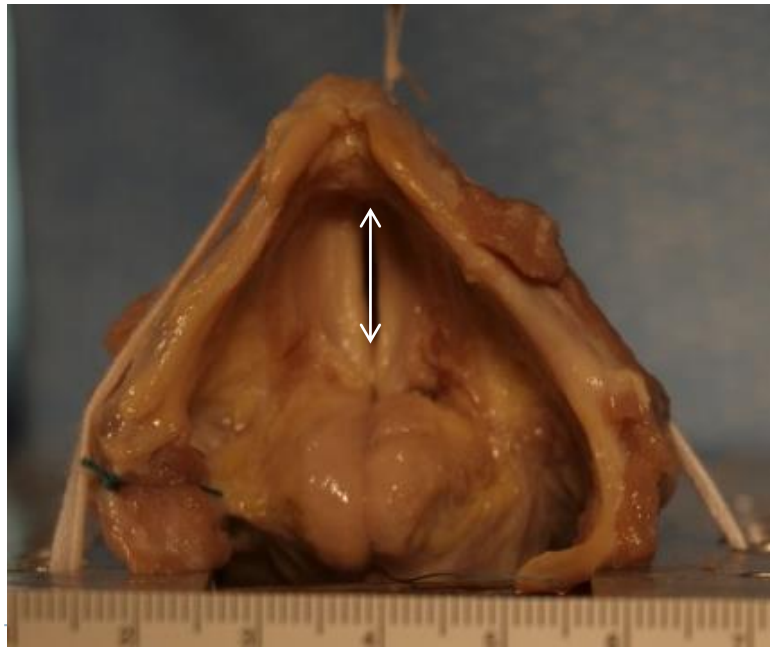
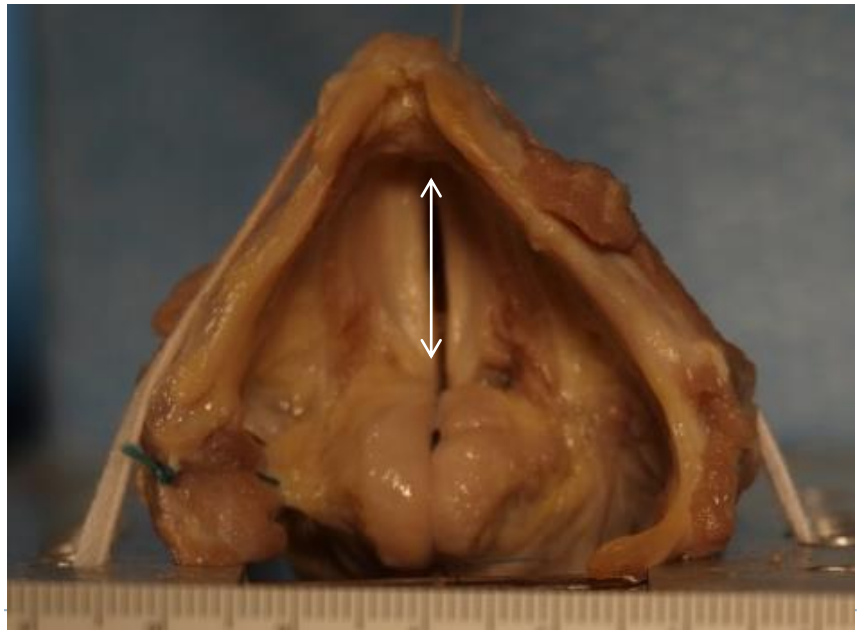
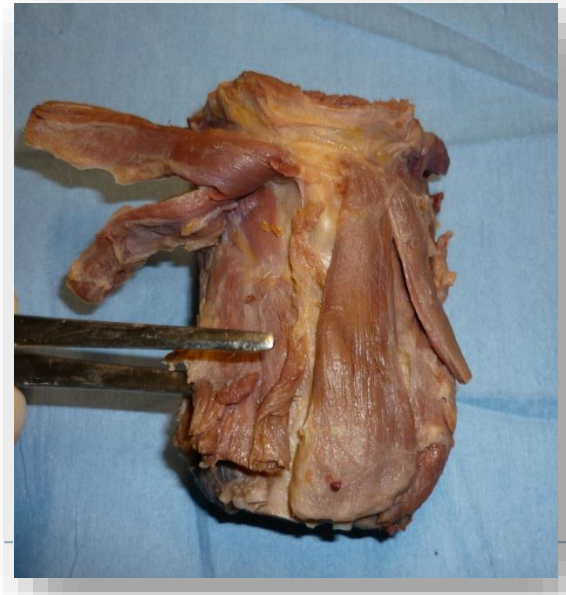




Muscles laryngés extrinsèques

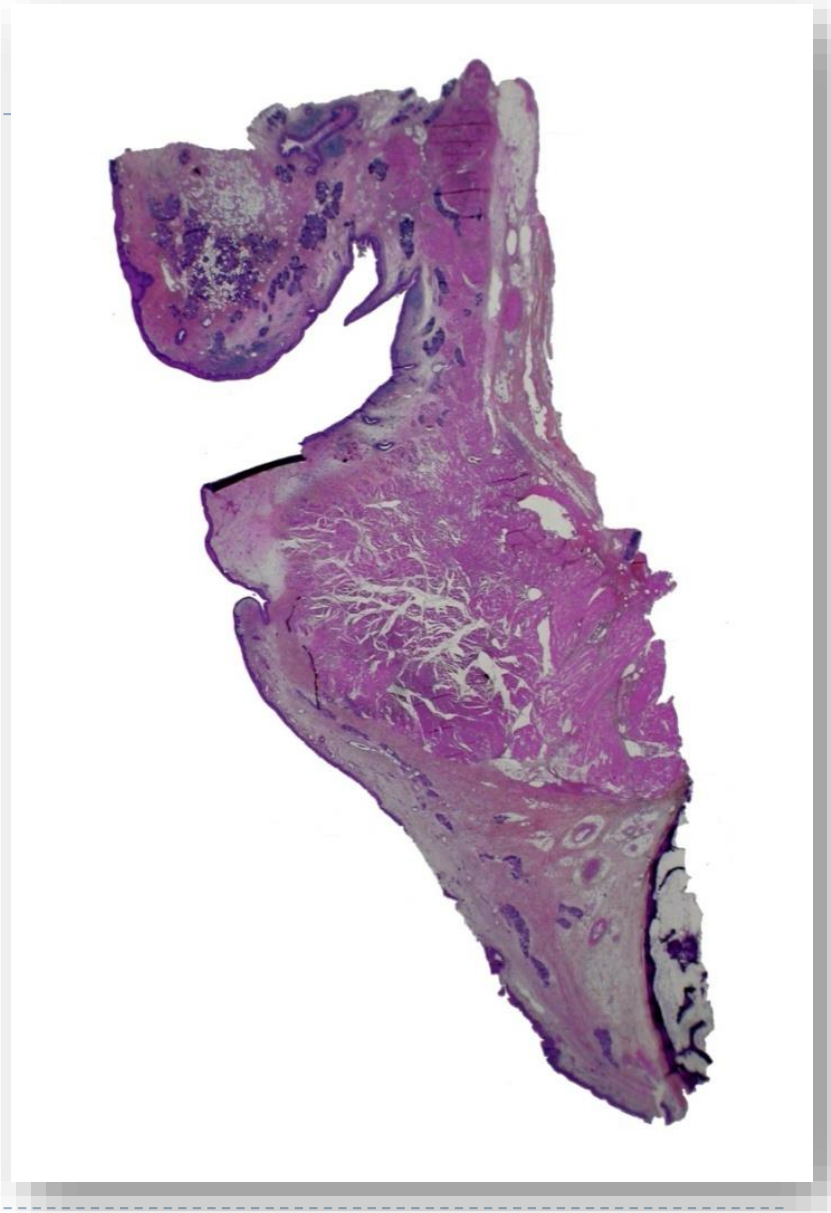
Muscles laryngés extrinsèques

- Muscles infra-hyoïdiens
  - Sterno-cléido-hyoïdien & omo-hyoïdien
  - Sterno-thyroïdien & thyro-hyoïdien

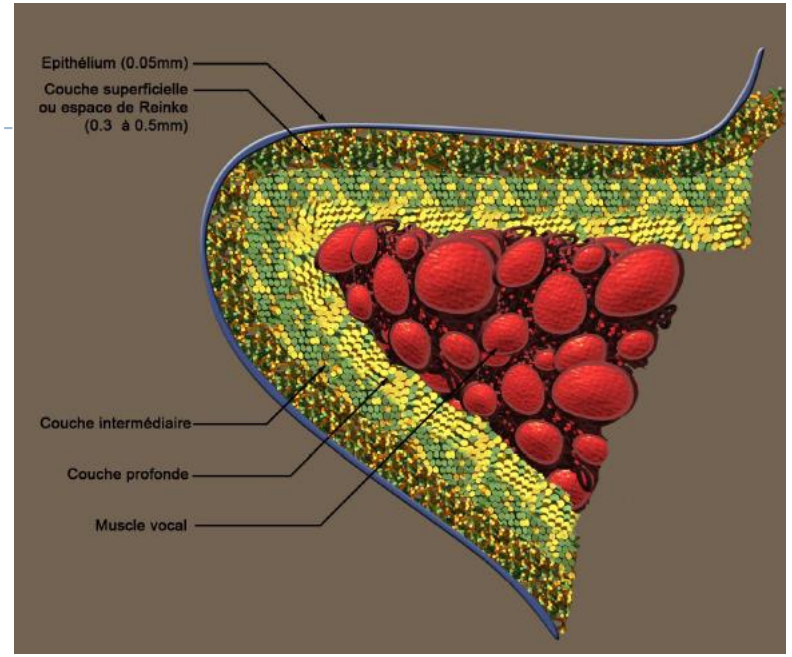


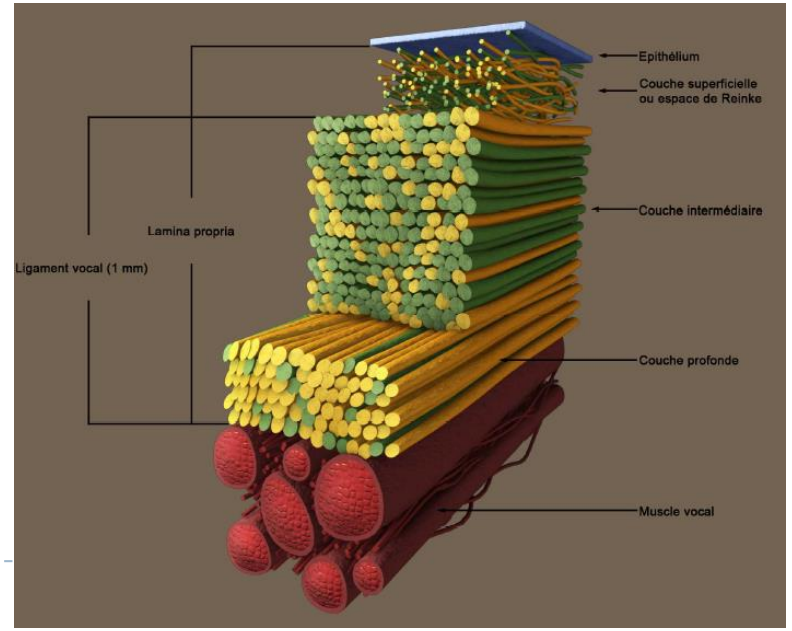
Micro-anatomie des plis vocaux

- Epithélium squameux non kératinisé
  - 50-100 µm d'épaisseur
  - Absence de glandes sur le bord libre, mais présence sur face inférieure



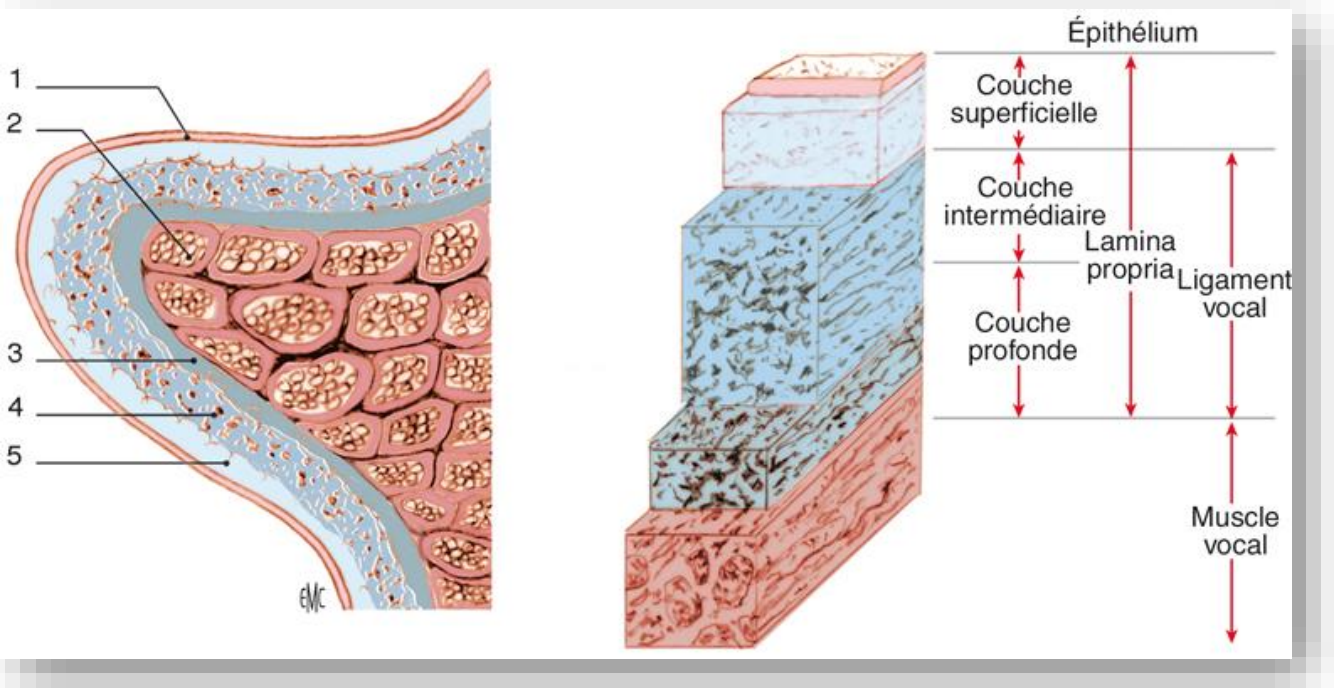
- Tissu conjonctif: lamina propria
  - 1-2,5mm d'épaisseur
  - Cellules conjonctives et matrice extra-cellulaire
  - 3 sous-couches:
    - Superficielle, espace de Reinke: composants fibreux lâches
    - Intermédiaire: fibres élastiques prédominantes
    - Profonde: collagène prédominant
  - Donne les propriétés mécaniques passives du pli





Finck C. Implantation d'acide hyaluronique estérifié lors de la microchirurgie des lésions cordales bénignes. Thèse de doctorat, 2008

- Muscle vocal
  - Chef inférieur du muscle thyro-aryténoïdien
  - Epaisseur: 7-8 mm
  - Donne les propriétés de contraction active du pli

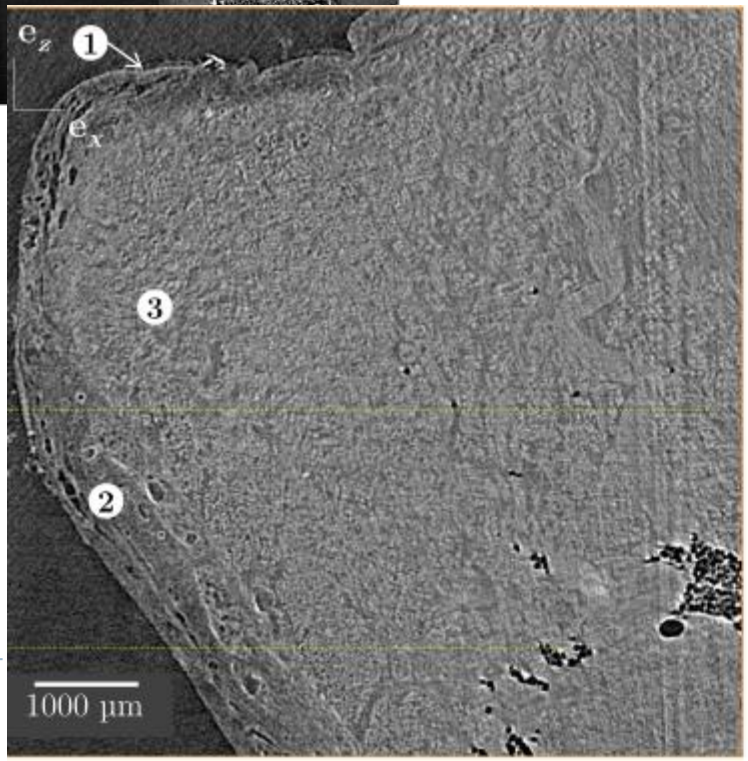


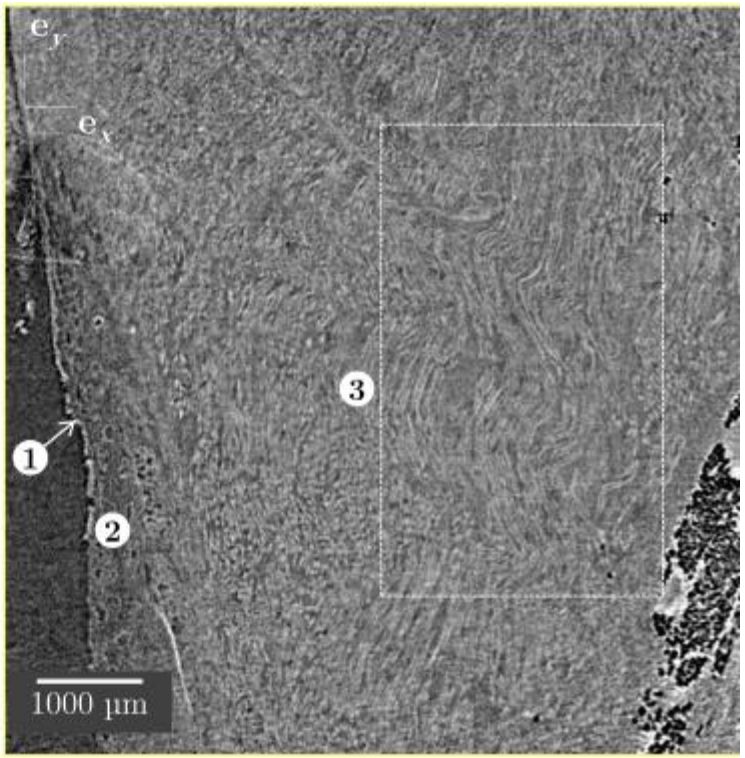
Physiologie de la phonation, EMC, A. Giovanni, A. Lagier, N. Henrich

3D multiscale imaging of human vocal folds using synchrotron X-ray microtomography in phase retrieval mode.

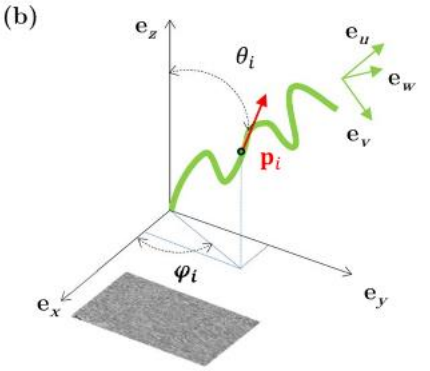
Bailly L, Cochereau T, Orgéas L, Henrich Bernardoni N, Rolland du Roscoat S, McLeer-Florin A, Robert Y, Laval X, Laurencin T, Chaffanjon P, Fayard B, Boller E.

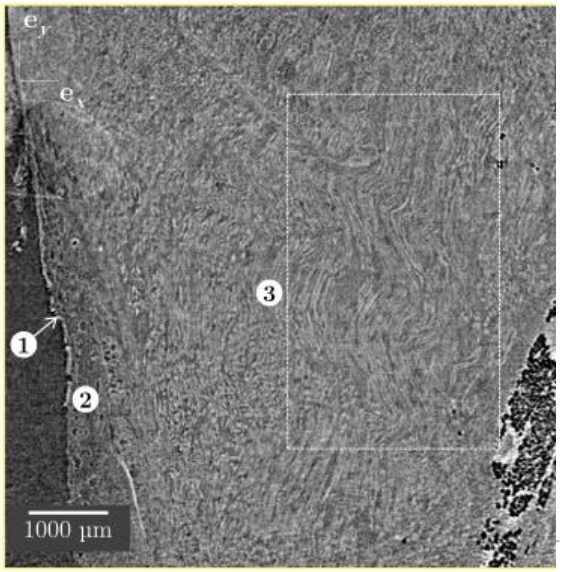
Sci Rep. 2018 Sep 18;8(1):14003. doi: 10.1038/s41598-018-31849-w.

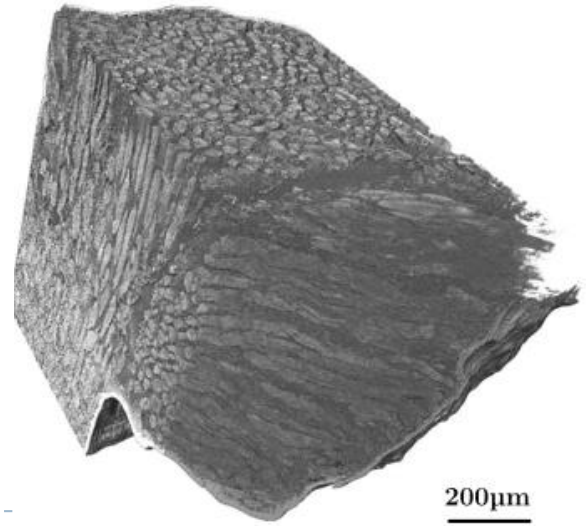


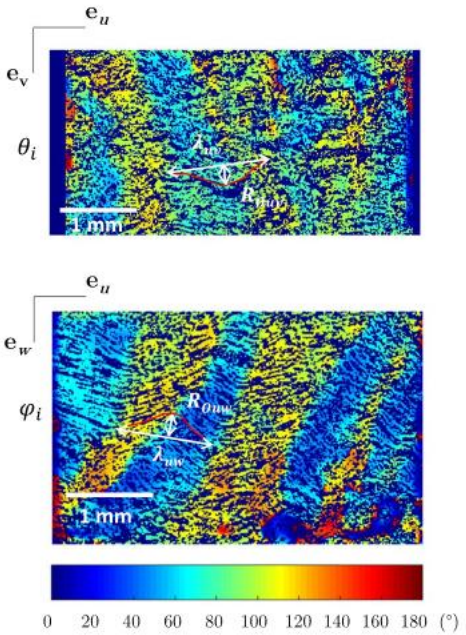


- Muscle vocal:
  - À proximité de la lamina propria,
    - Fibres orientées longitudinalement
  - Au-delà de 1 mm de la lamina propria,
    - Fibres parfois orientées perpendiculairement
    - Transition entre muscle vocal muscle crico-aryténoïdien latéral

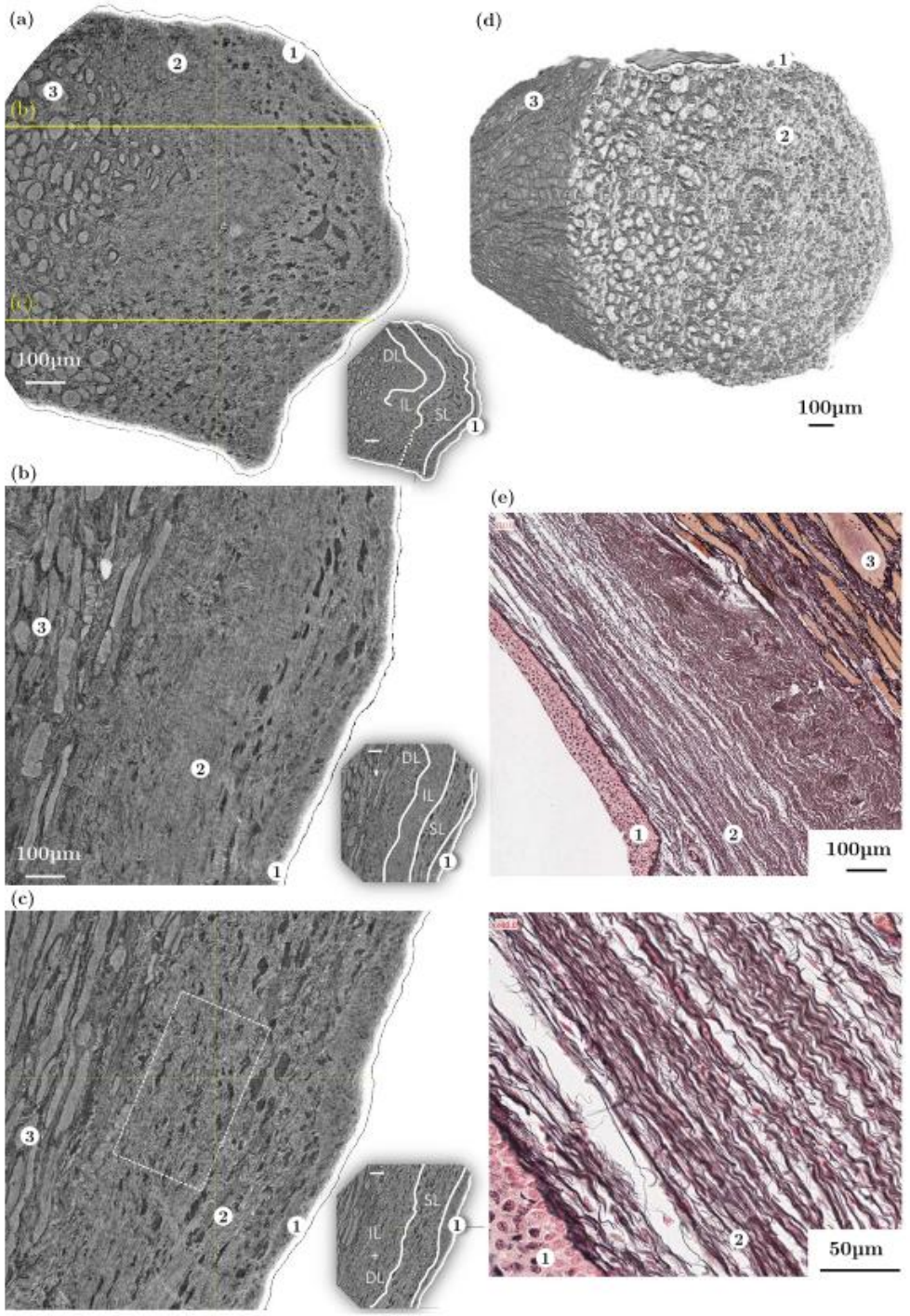




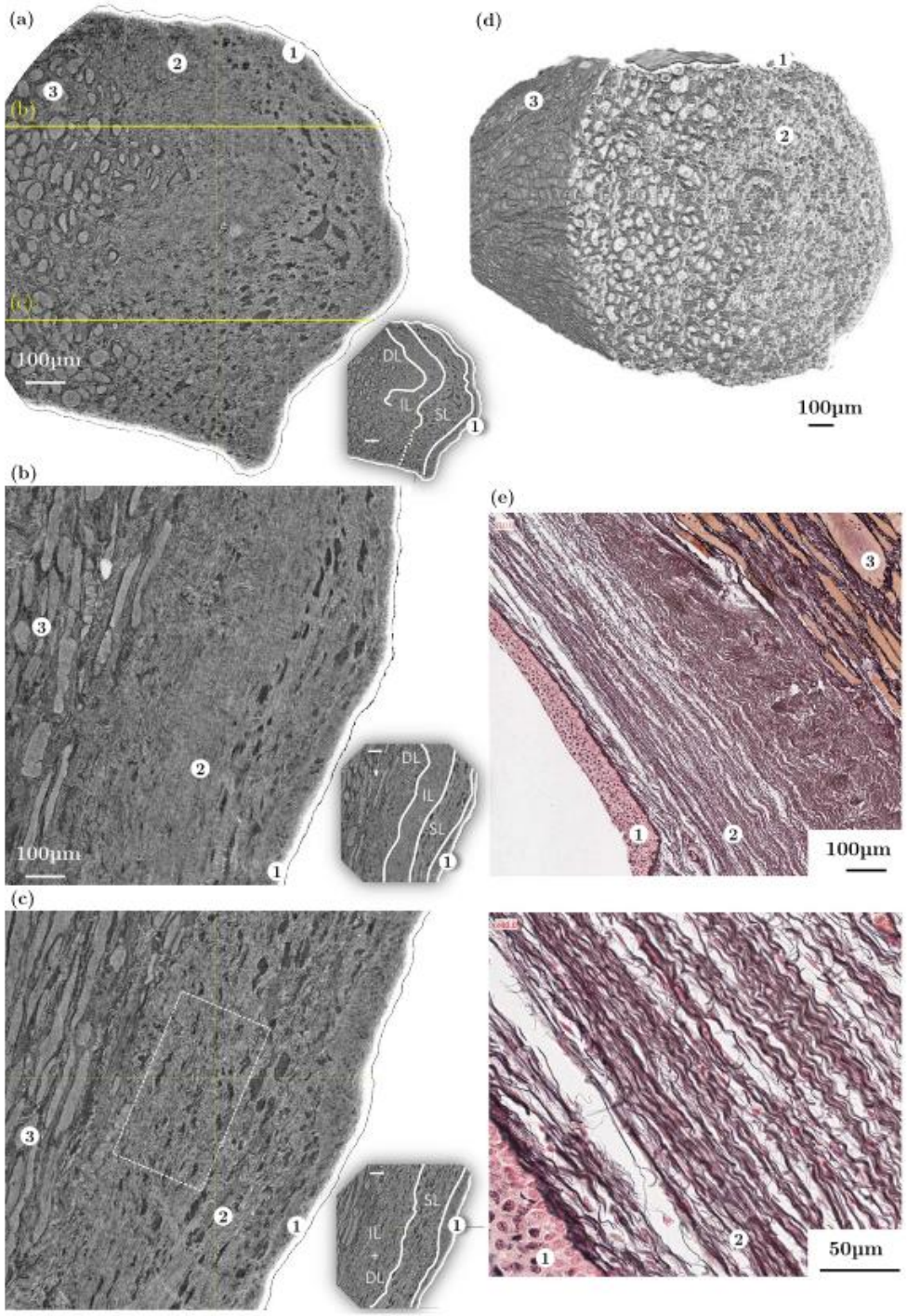




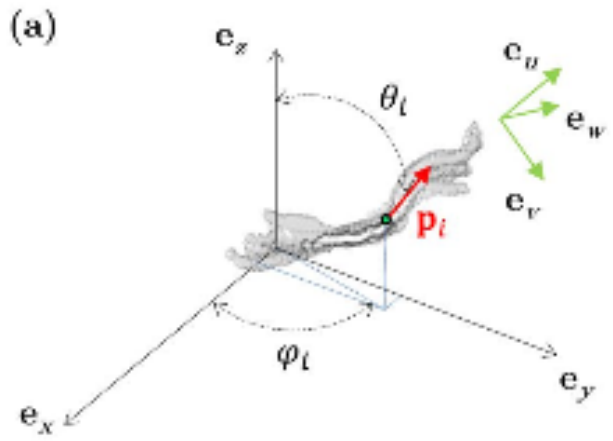
- Epithélium
  - Plus épais au 1/3 moyen du bord libre
    - 30 -> 80µm

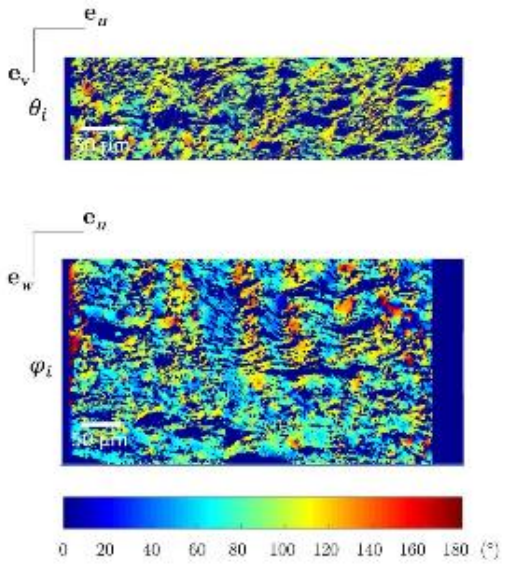


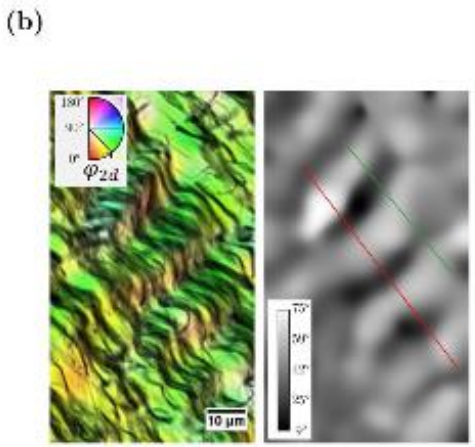
- Lamina propria
  - Plus épaisse au 1/3 moyen
  - Asymétrie d'épaisseur entre les plis (780-2054 µm)
  - Partie superficielle:
    - densité de fibre moins importante dans la matrice extra-cellulaire
    - Epaisseur variable: 100-200 µm
  - Partie intermédiaire:
    - plus grande densité de fibres,
    - Elastine
    - Pas toujours identifiable, plutôt présente au 1/3 moyen
  - Partie profonde:
    - fibres plus denses et plus épaisses,
    - collagène

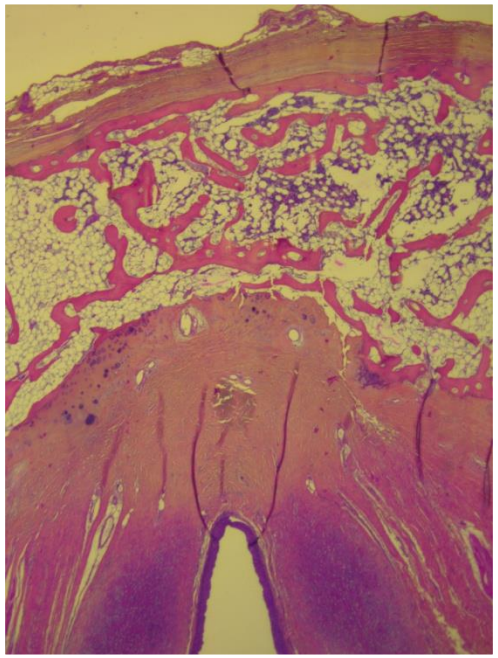


- Orientation des fibres (collagène) dans la lamina propria
  - Longitudinale, légère obliquité en antéro-postérieur et médio-latéral
  - Ondulée
  - Diamètre 50µm, longueur: 400 µm



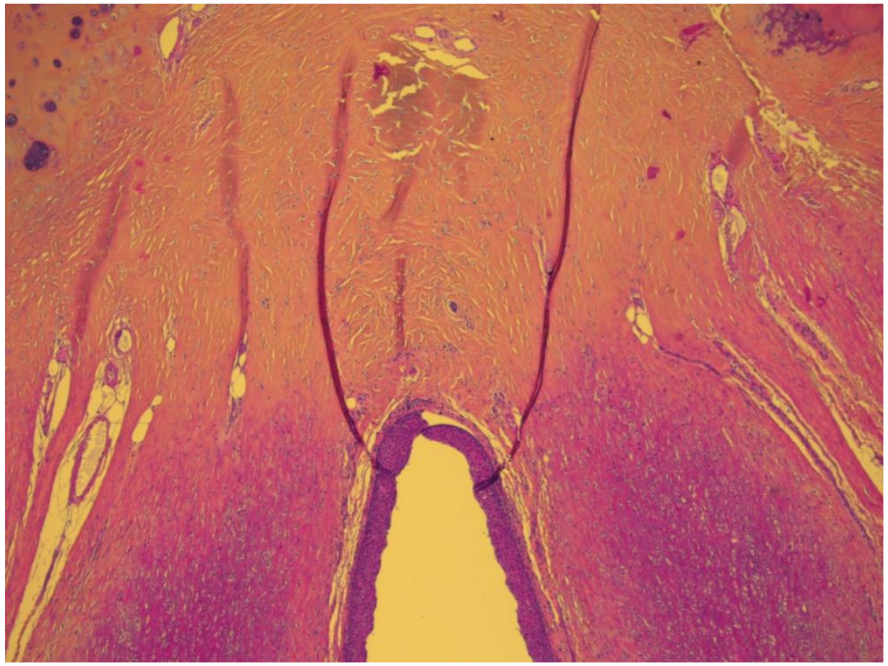


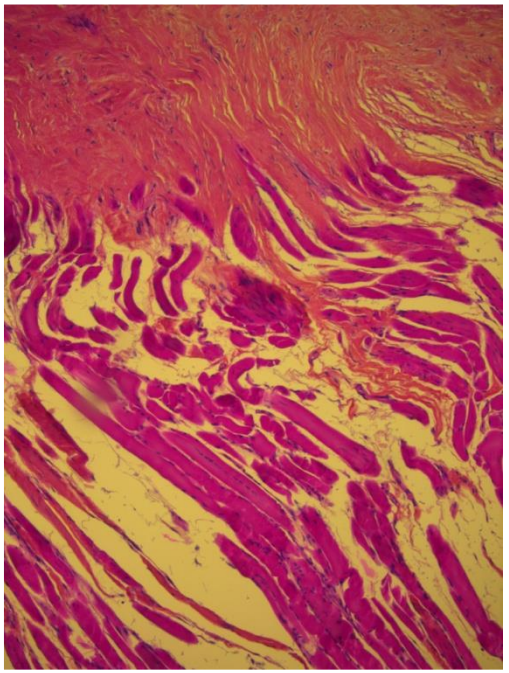




Commissure antérieure

- Maculae flavae
- Absence de périchondre



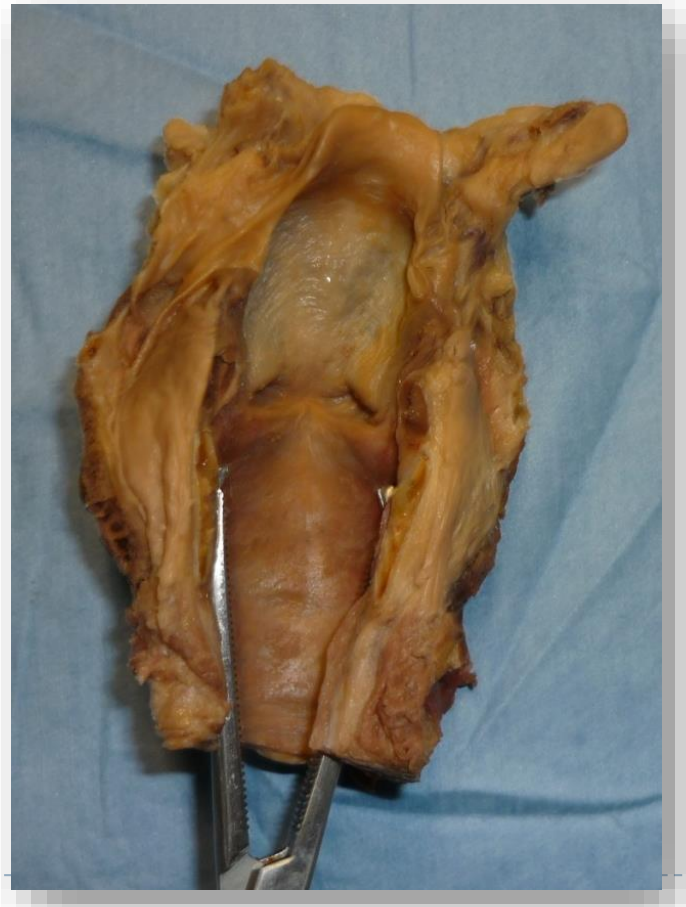


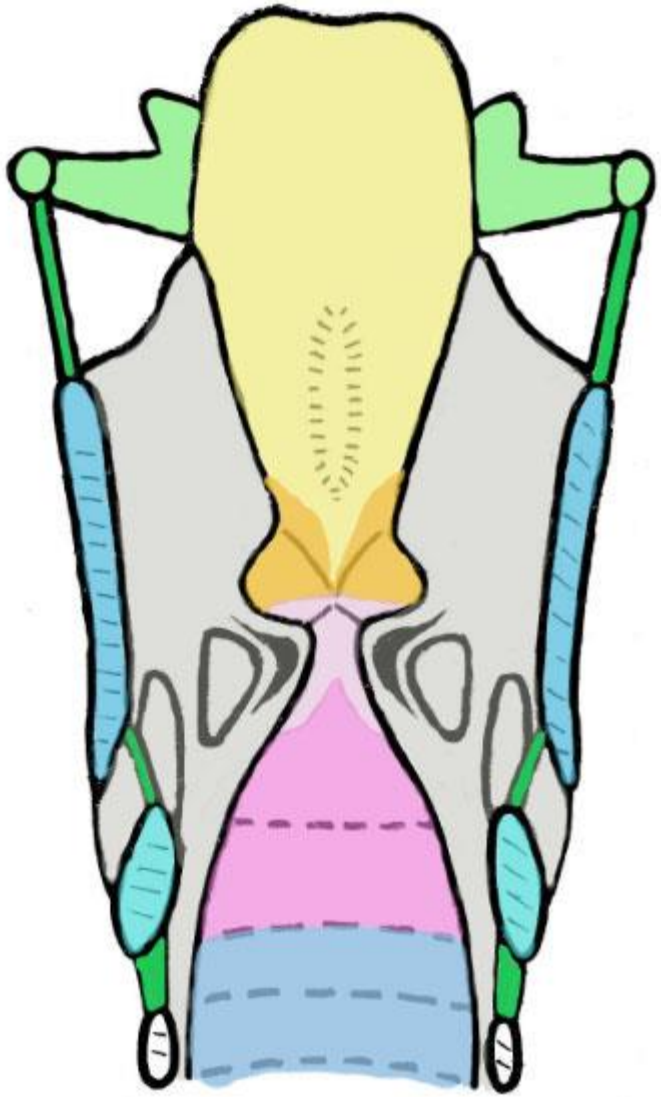
The anterior commissure of the human larynx revisited.Prades JM, Peoc'h M, Petcu C, Karkas A, Dumollard JM, Gavid M. Surg Radiol Anat. 2017 Aug;39(8):871-876.

Reliefs internes du larynx

Le larynx

Reliefs internes



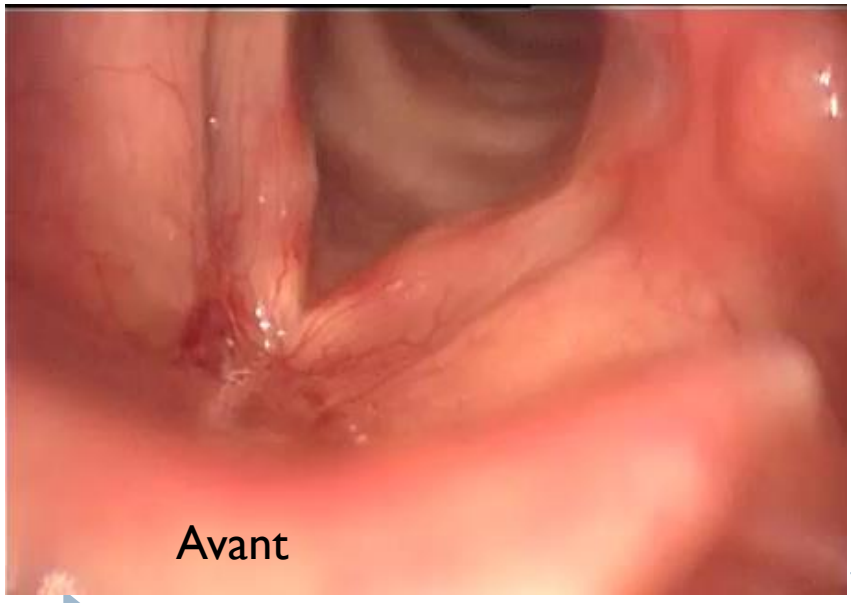

Haut
Gauche

Vues endoscopiques du larynx

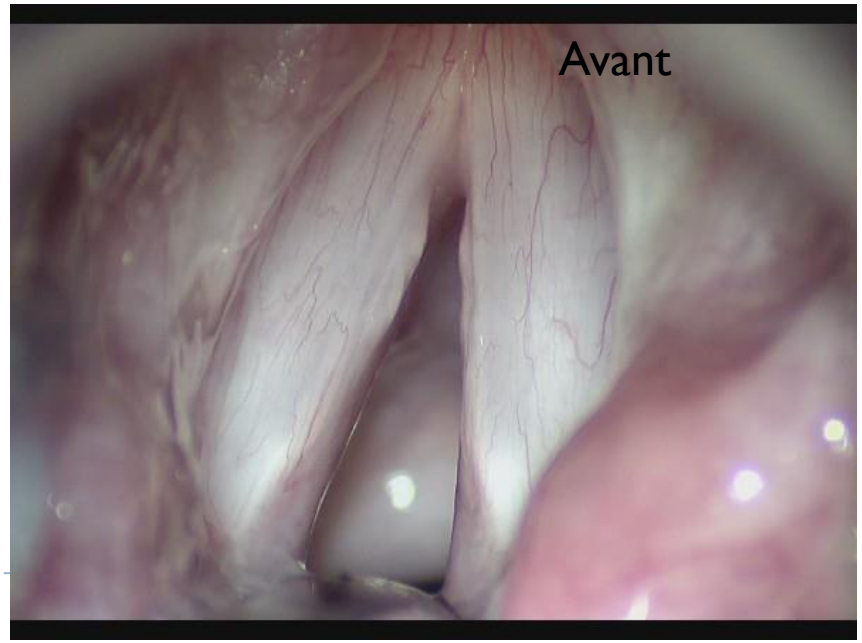
Vue endoscopique du larynx

- Attention au sens!

Laryngoscopie indirecte

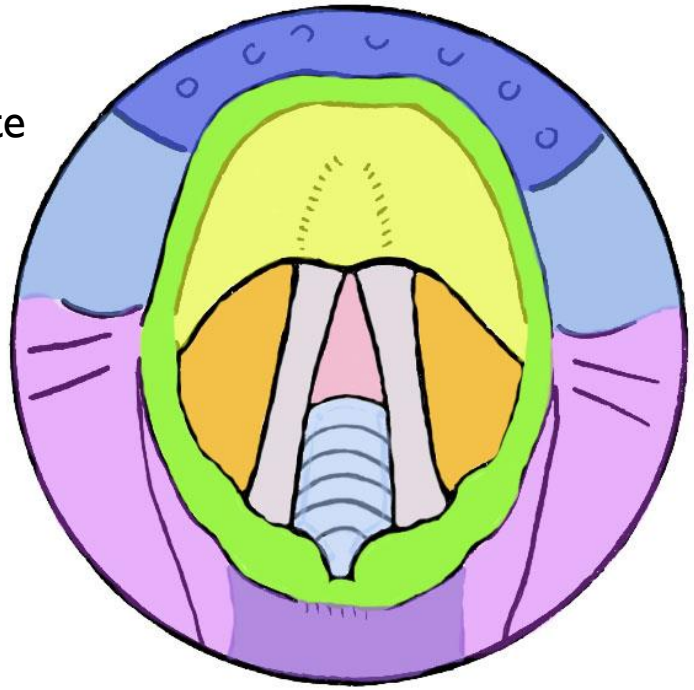


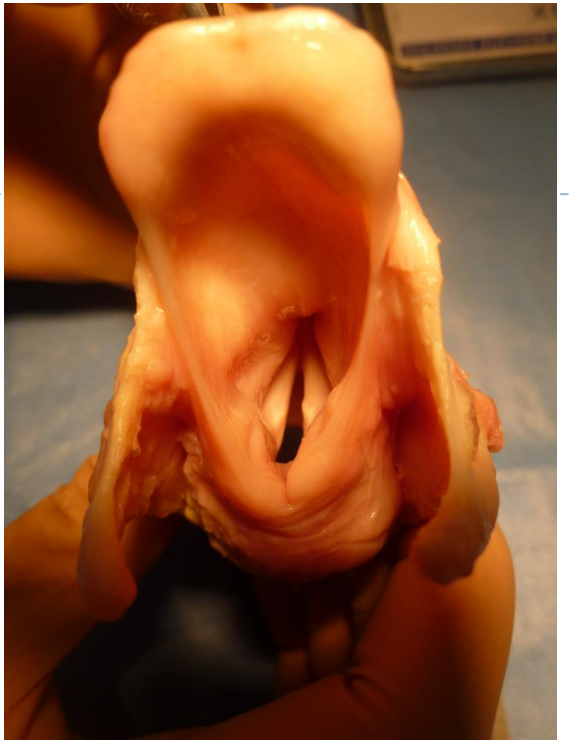
Laryngoscopie directe en suspension



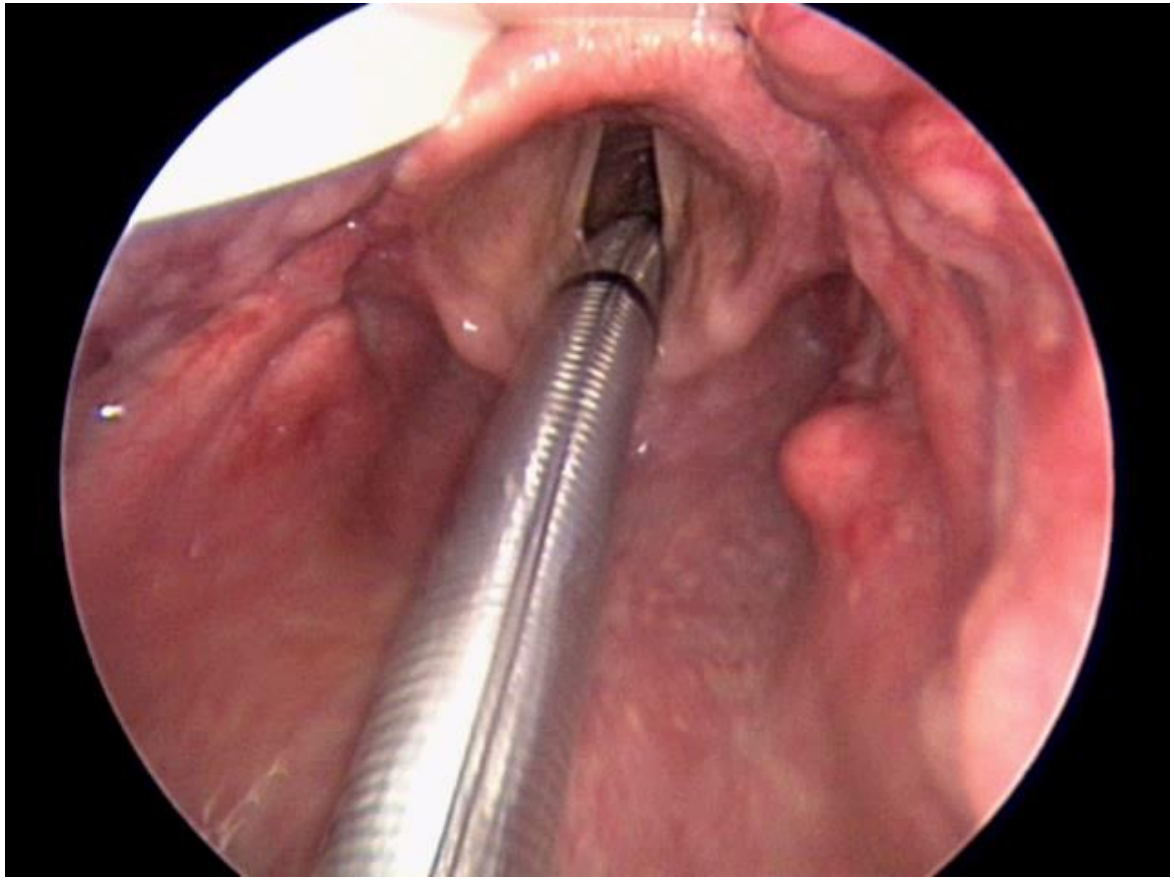
Avant

Droite





Vue endoscopique du larynx



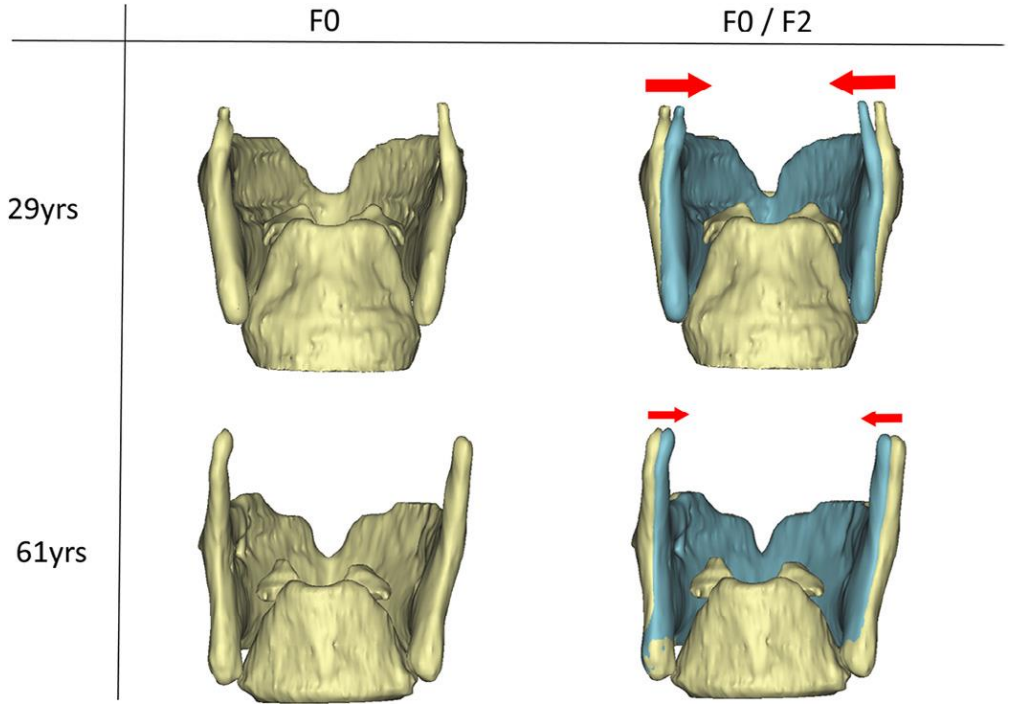
Anatomie fonctionnelle

Les caractéristiques de la voix dépendent:

- Des paramètres aérodynamiques/contrôle respiratoire
  - Pression sous-glottique et trans-glottique
  - Débit d'air
- **Des propriétés physiques des plis vocaux**
  - **Longueur, tension, masse vibrante, raideur**
- Des résonateurs/tractus vocal

Le vibrateur et ses modifications

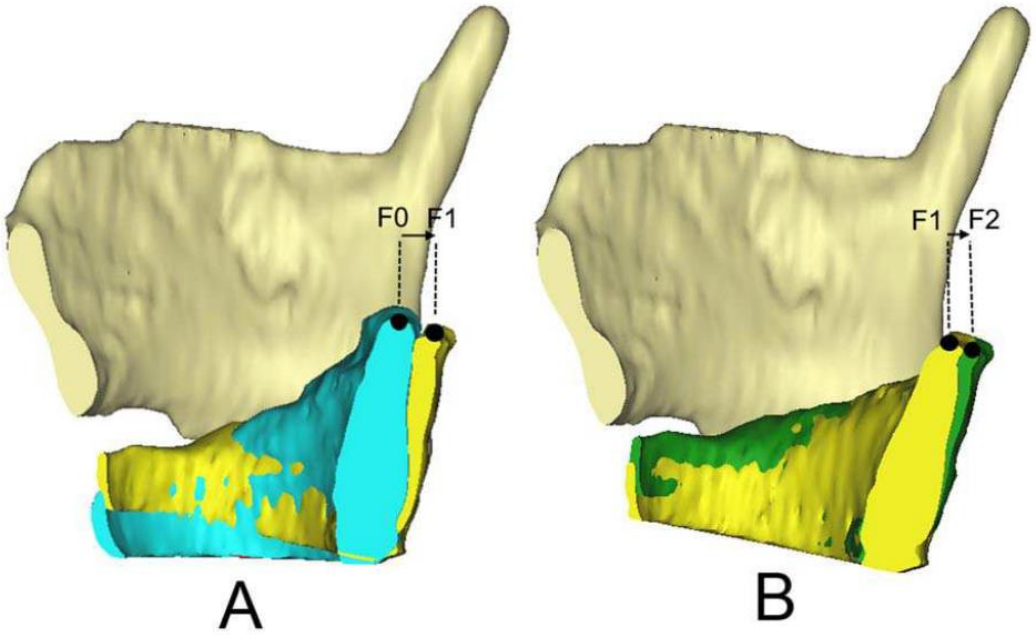
Modifications cartilagineuses



- 44 chanteuses professionnelles
- Hauteur parlée puis 1 et 2 octaves au-dessus

Unteregger F, Thommen J, Honegger F, Potthast S, Zwicky S, Storck C. How Age and Frequency Impact the Thyroid Cartilages of Professional Singers. J Voice. 2018 Jan 8. pii: S0892-1997(17)30395-8. doi: 10.1016/j.jvoice.2017.11.017.

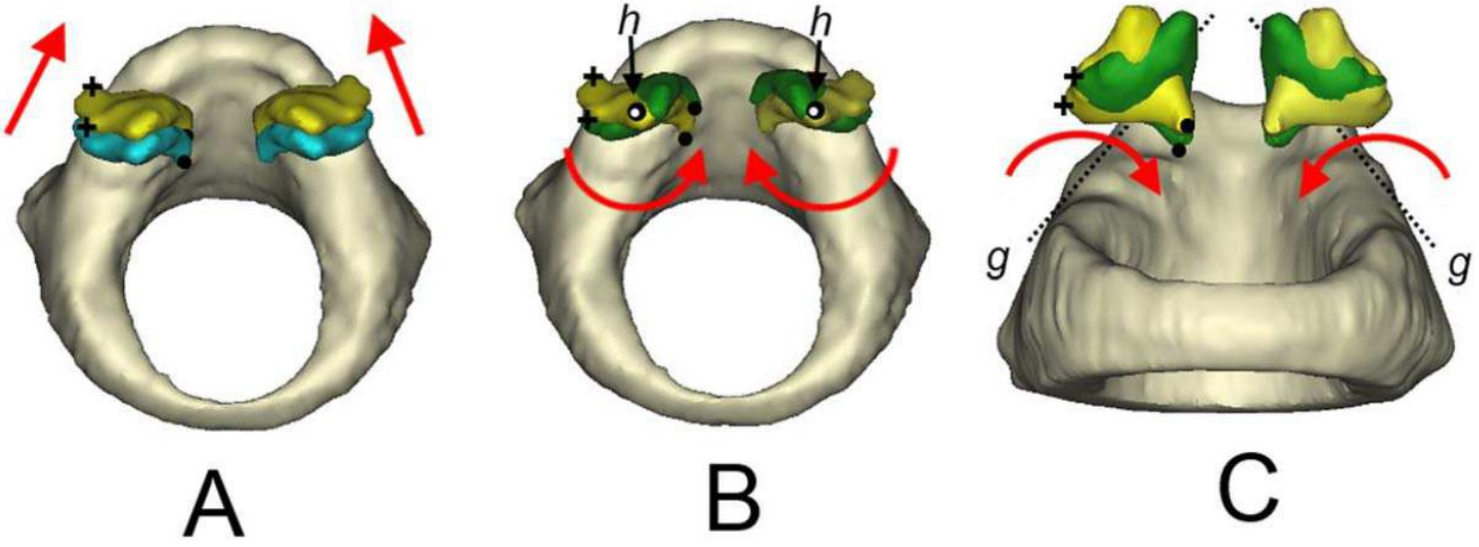
Modifications cartilagineuses



- Même cohorte, même tâche
- Rotation postérieure du cartilage cricoïde

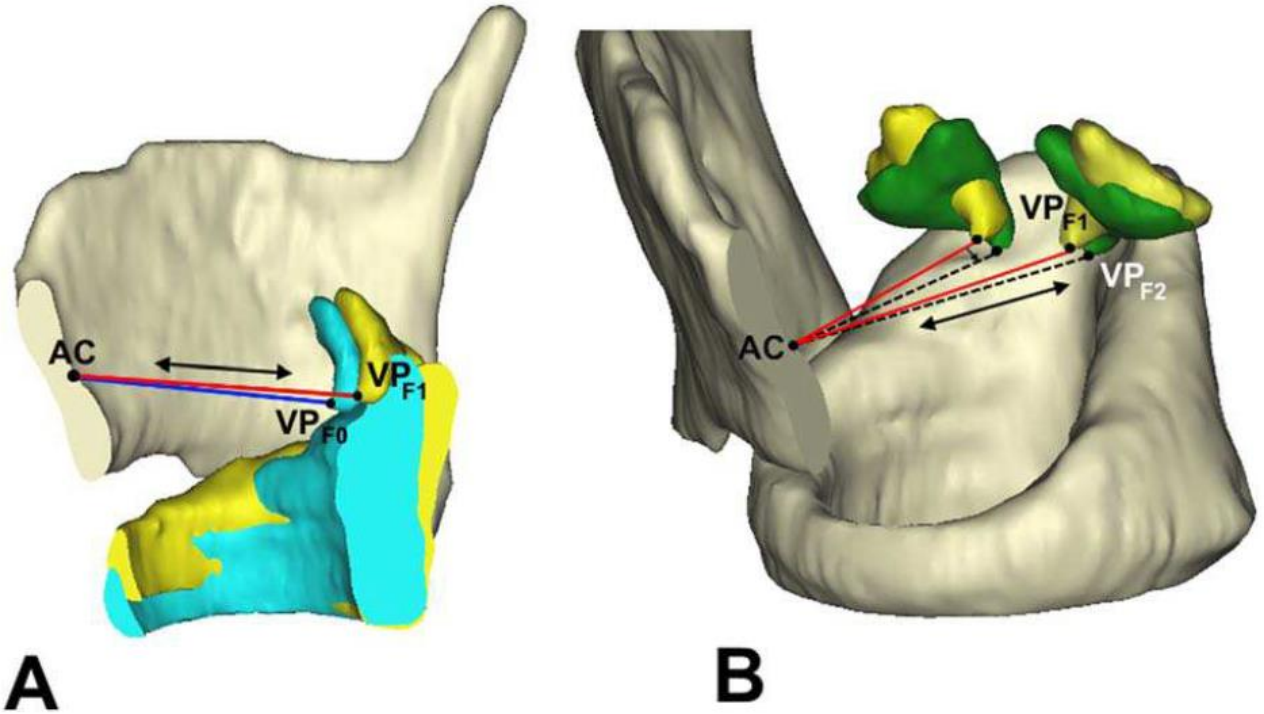
Unteregger F, Honegger F, Potthast S, Zwicky S, Schiwowa J, Storck C.3D analysis of the movements of the laryngeal cartilages during singing. Laryngoscope. 2017 Jul;127(7):1639-1643. doi: 10.1002/lary.26430.

Modifications cartilagineuses



- Entre F0 et F1, le mouvement des aryténoïdes est passif, lié au mouvement du cricoïde
- Entre F1 et F2, il devient plus complexe qui porte le processus vocal en arrière et en bas

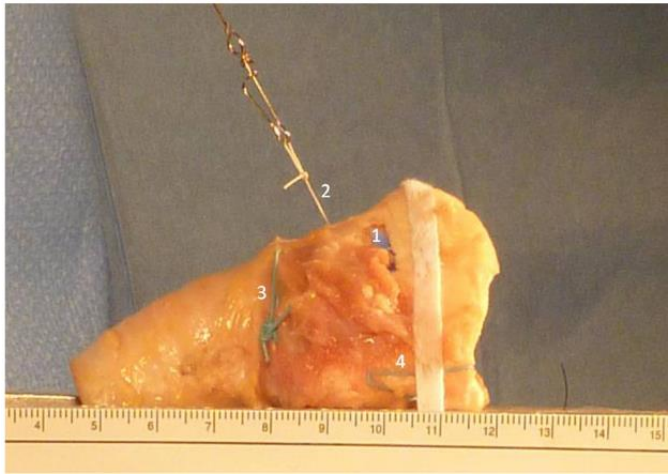
Modifications cartilagineuses[2]

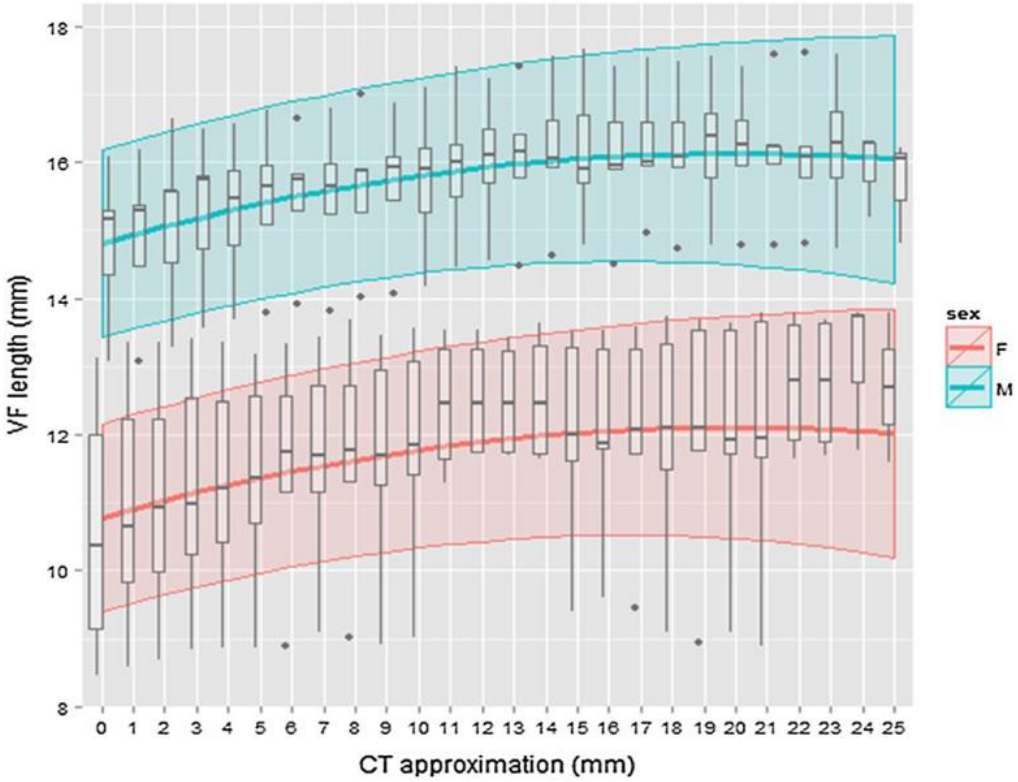


- Entre F0 et F1, le mouvement des aryténoïdes est passif, lié au mouvement du cricoïde
- Entre F1 et F2, il devient plus complexe qui porte le processus vocal en arrière et en bas

Unteregger F, Honegger F, Potthast S, Zwicky S, Schiwowa J, Storck C.3D analysis of the movements of the laryngeal cartilages during singing. Laryngoscope. 2017 Jul;127(7):1639-1643. doi: 10.1002/lary.26430.

Elongation des plis vocaux[3]

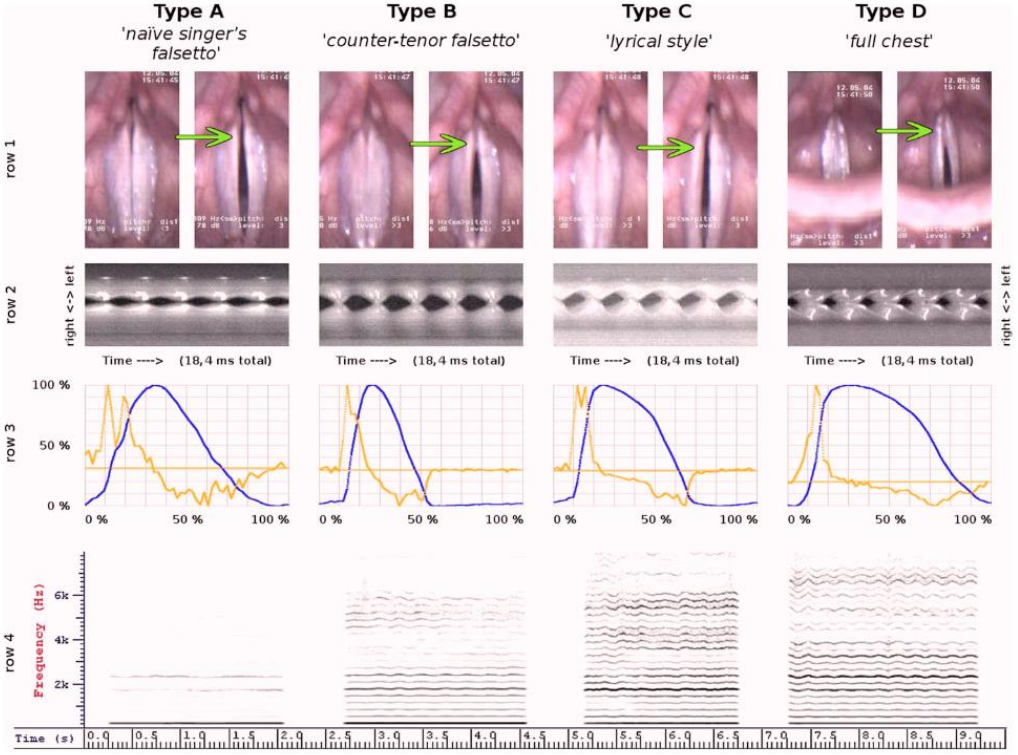




- Elongation maximale de 10 à 15%
- Soit de 1 à 2 mm de plus en moyenne
- Approximation CT maximale: 22 mm

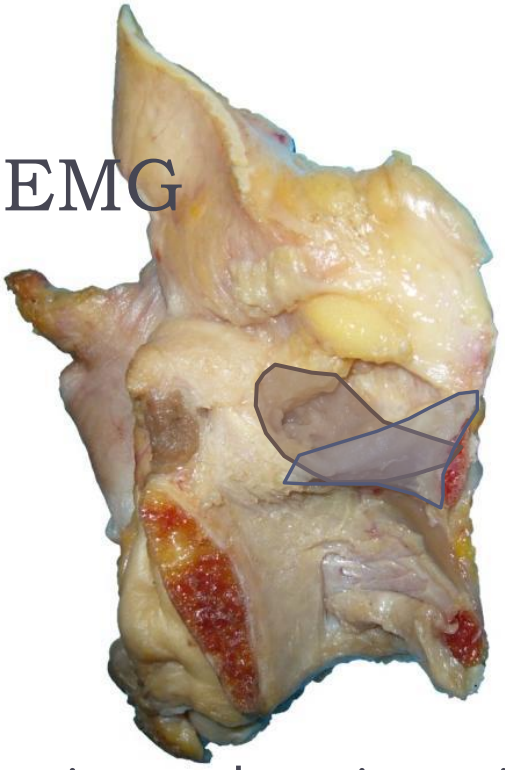
Lagier A, Guenoun D, Legou T, Espesser R, Giovanni A, Champsaur P. Control of the glottal configuration in ex vivo human models: quantitative anatomy for clinical and experimental practices. Surg Radiol Anat. 2017 Mar;39(3):257-262. doi: 10.1007/s00276-016-1738-2.

Configurations glottiques et style[4]



Herbst CT, Ternström S, Svec JG.Investigation of four distinct glottal configurations in classical singing--a pilot study. J Acoust Soc Am. 2009 Mar;125(3):EL104-9. doi: 10.1121/1.3057860.

Activité des muscles intrinsèques: Etudes EMG



- En voix parlée:
  - Activation du CAL lors de la mise en phonation, puis seulement activité du TA
- En voix chantée:
  - EMG du muscle thyro-aryténoïdien et du crico-thyroïdien en registre de poitrine, mixte de poitrine, mixte de tête, de tête
    - Activité du CT liée à la fréquence principalement (>registre)
    - Activité du TA et adduction cordale augmentent du registre de tête au registre de poitrine

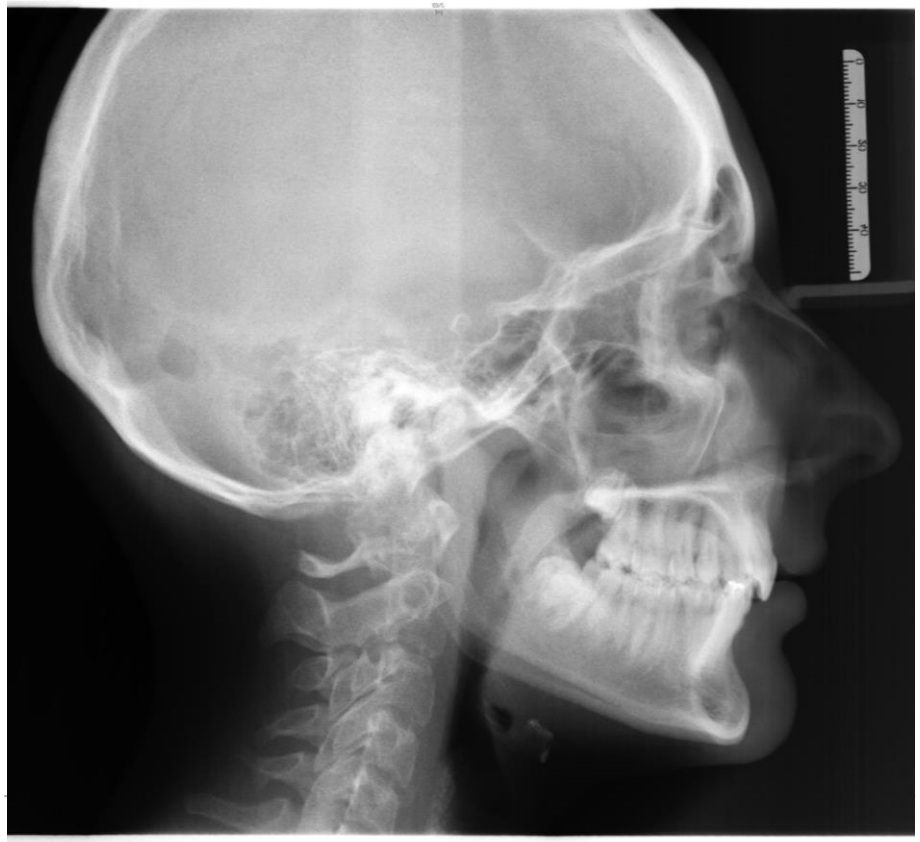
-Poletto CJ, Verdun LP, Strominger R, Ludlow CL (2004) Correspondence between laryngeal vocal fold movement and muscle activity during speech and nonspeech gestures. J Appl Physiol (1985) 97,858-866
-Kochis-Jennings KA, Finnegan EM, Hoffman HT, Jaiswal S. Laryngeal muscle activity and vocal fold adduction during chest, chestmix, headmix, and head registers in females. J Voice. 2012 Mar;26(2):182-93. doi: 10.1016/j.jvoice.2010.11.002

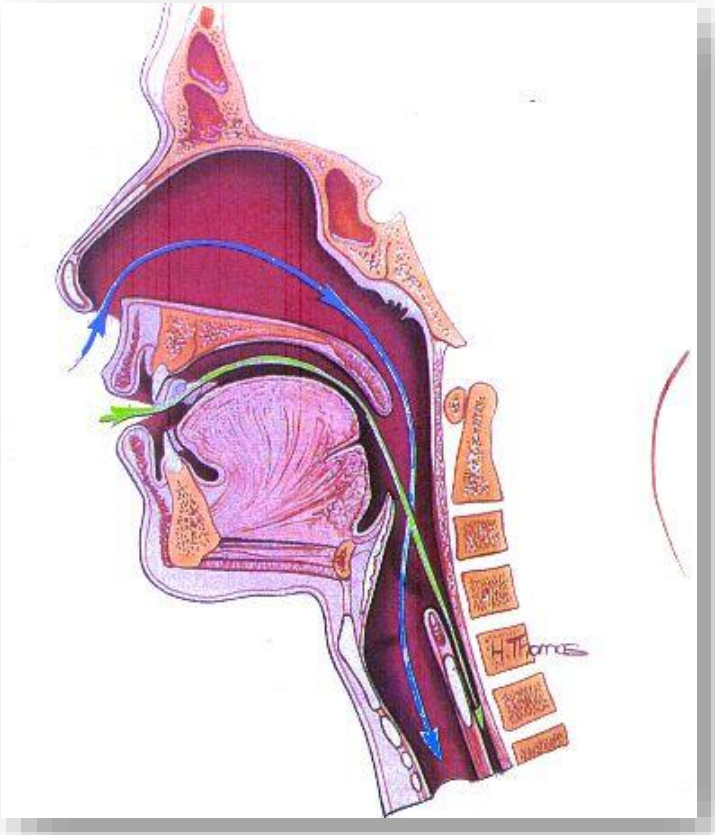
Les résonateurs

Les caractéristiques de la voix dépendent:

- Des paramètres aérodynamiques/contrôle respiratoire
  - Pression sous-glottique et trans-glottique
  - Débit d'air
- Des propriétés physiques des plis vocaux
  - Longueur, tension, masse vibrante, raideur
- **Des résonateurs/tractus vocal**

Les résonateurs





Les résonateurs

https://youtu.be/QAWtle1q9QU

- Baryton:
  - Pour éviter un changement de registre
    - Elévation du dorsum lingual
    - Ouverture de la machoire
    - Rétraction de la mandibule

Echternach M, Traser L, Markl M, Richter B.Vocal tract configurations in male alto register functions. J Voice. 2011 Nov;25(6):670-7. doi: 10.1016/j.jvoice.2010.09.008.

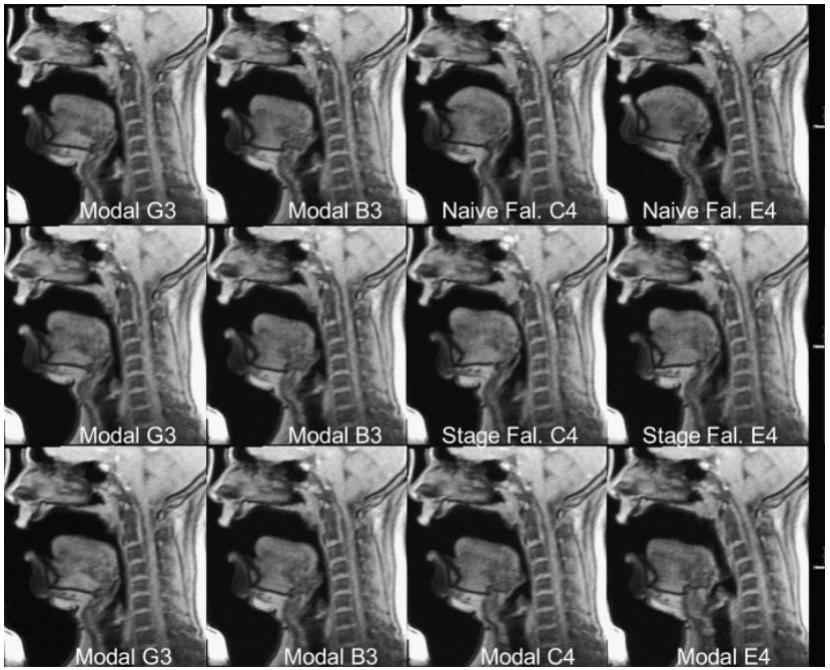
Les résonateurs

- Ténors:
  - Constriction de l'épilarynx dans la partie haute de la tessiture (passage en falsetto ET passage en voix de scène)
  - Passage du registre modal au falsetto « novice »
    - Peu de modifications du tractus vocal
  - Passage du registre modal au falsetto « de scène »
    - Modifications importantes
    - Élargissement du pharynx
    - Ouverture des lèvres et machoires
    - Protrusion de la mandibule

Echternach M, Traser L, Markl M, Richter B.Vocal tract configurations in male alto register functions. J Voice. 2011 Nov;25(6):670-7. doi: 10.1016/j.jvoice.2010.09.008.
Echternach M, Burk F, Köberlein M, Herbst CT, Döllinger M, Burdumy M, Richter B. Oscillatory Characteristics of the Vocal Folds Across the Tenor Passaggio. J Voice. 2017 May;31(3):381.e5-381.e14. doi: 10.1016/j.jvoice.2016.06.015.

Les résonateurs

- Contre-ténors

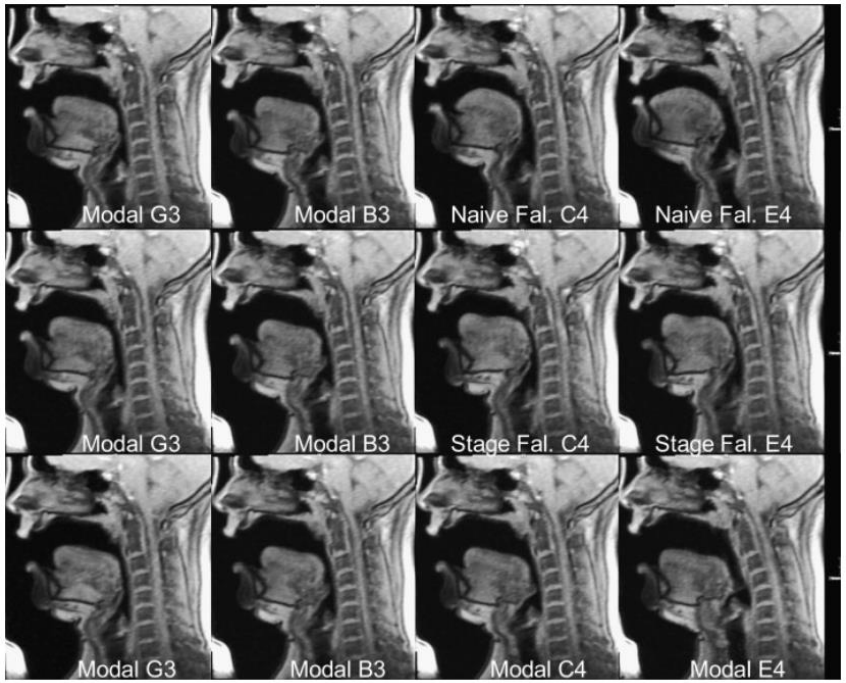


- Registre modal à falsetto de scène:
  - Ouverture soudaine des lèvres alors que dans la montée en registre modal les lèvres s'ouvrent progressivement
  - Ouverture des machoires
- En falsetto de scène, la machoire est rétractée, et le dorsum de la langue est élevé et en arrière, le pharynx est rétréci
- Au contraire en registre modal dans les aigus, la mandibule est avancée et le pharynx élargi

Echternach M, Traser L, Markl M, Richter B.Vocal tract configurations in male alto register functions. J Voice. 2011 Nov;25(6):670-7. doi: 10.1016/j.jvoice.2010.09.008.

Les résonateurs

- Contre-ténors



- Le voile du palais est élevé dans les aigus quel que soit le registre, mais élévation plus soudaine lors du changement de registre
- Les aigus en registre modal s'accompagnent d'une élévation progressive du larynx alors que le passage en falsetto s'accompagne d'une descente du larynx
- Le plan glottique est plus oblique dans les falsetto

Echternach M, Traser L, Markl M, Richter B.Vocal tract configurations in male alto register functions. J Voice. 2011 Nov;25(6):670-7. doi: 10.1016/j.jvoice.2010.09.008.

Les résonateurs

https://www.youtube.com/watch?v=YIUvX7hebBA&feature=youtu.be&app=desktop

- Soprani
  - Transition entre les mécanismes laryngés et entre registres plus difficile à montrer chez les femmes
  - Peu de modification du tractus vocal lors des changements de registre (modal ->moyen->haut)
  - Modifications du tractus importantes pour éviter que F0 >F1 (750 Hz): ouverture des lèvres et machoires pour élever F1, élargissement du pharynx pour élever F2

Echternach M, Sundberg J, Arndt S, Markl M, Schumacher M, Richter B. Vocal tract in female registers--a dynamic real-time MRI study. J Voice. 2010 Mar;24(2):133-9. doi: 10.1016/j.jvoice.2008.06.004.

Les résonateurs

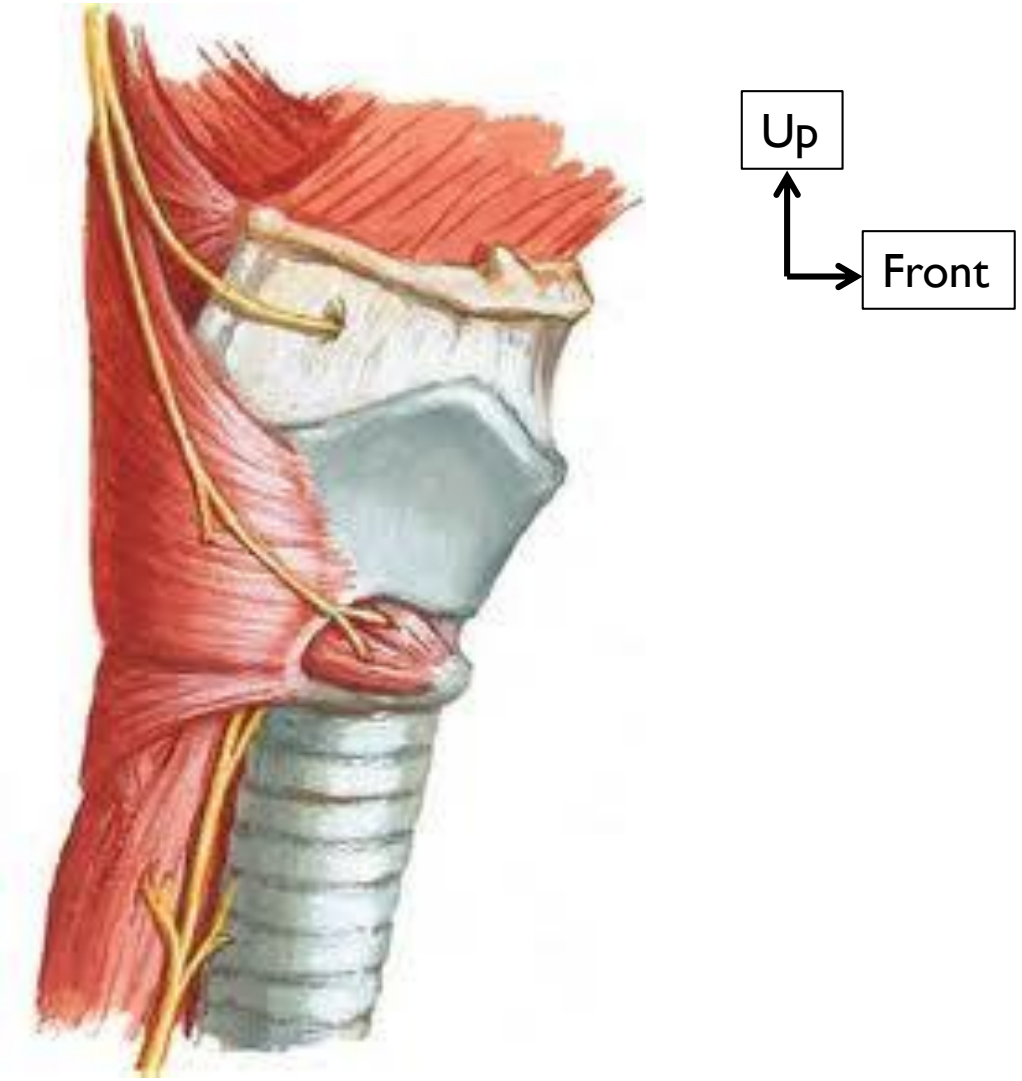
- Juste pour le plaisir….

Merci pour votre attention,
Si vous avez des questions:

aude.lagier@chuliege.be

Laryngeal innervation

Laryngeal innervation



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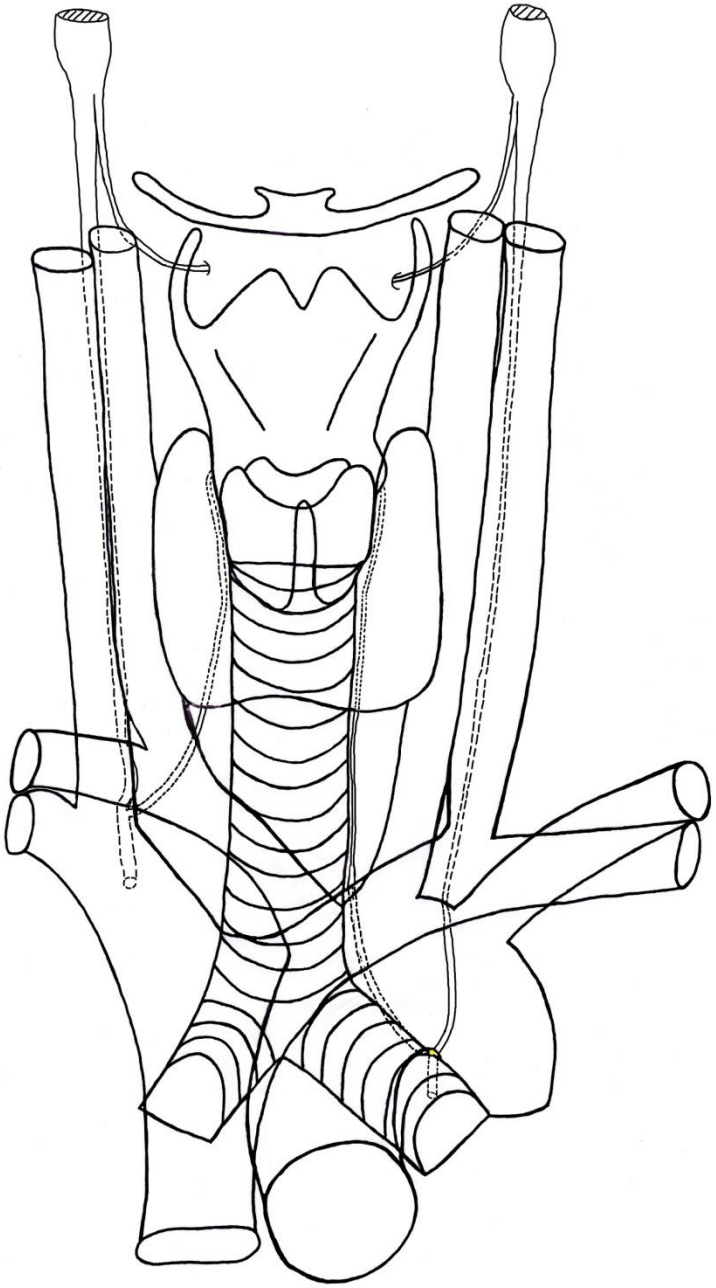

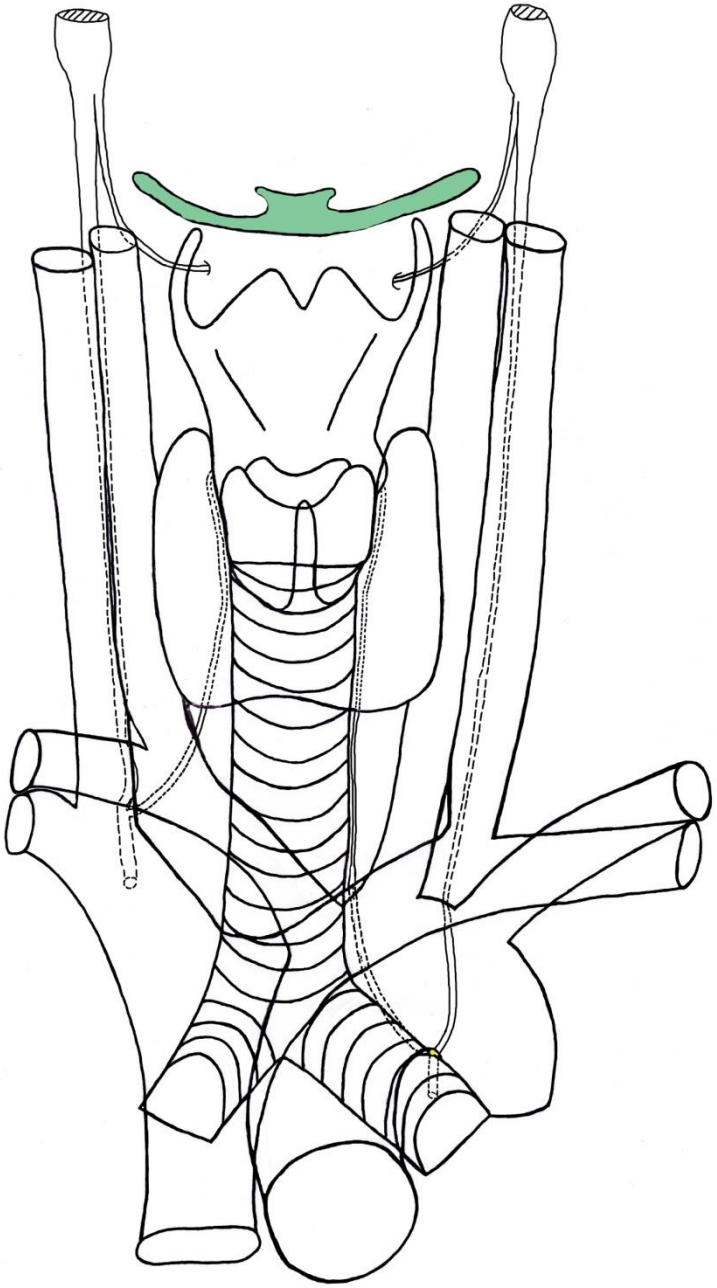
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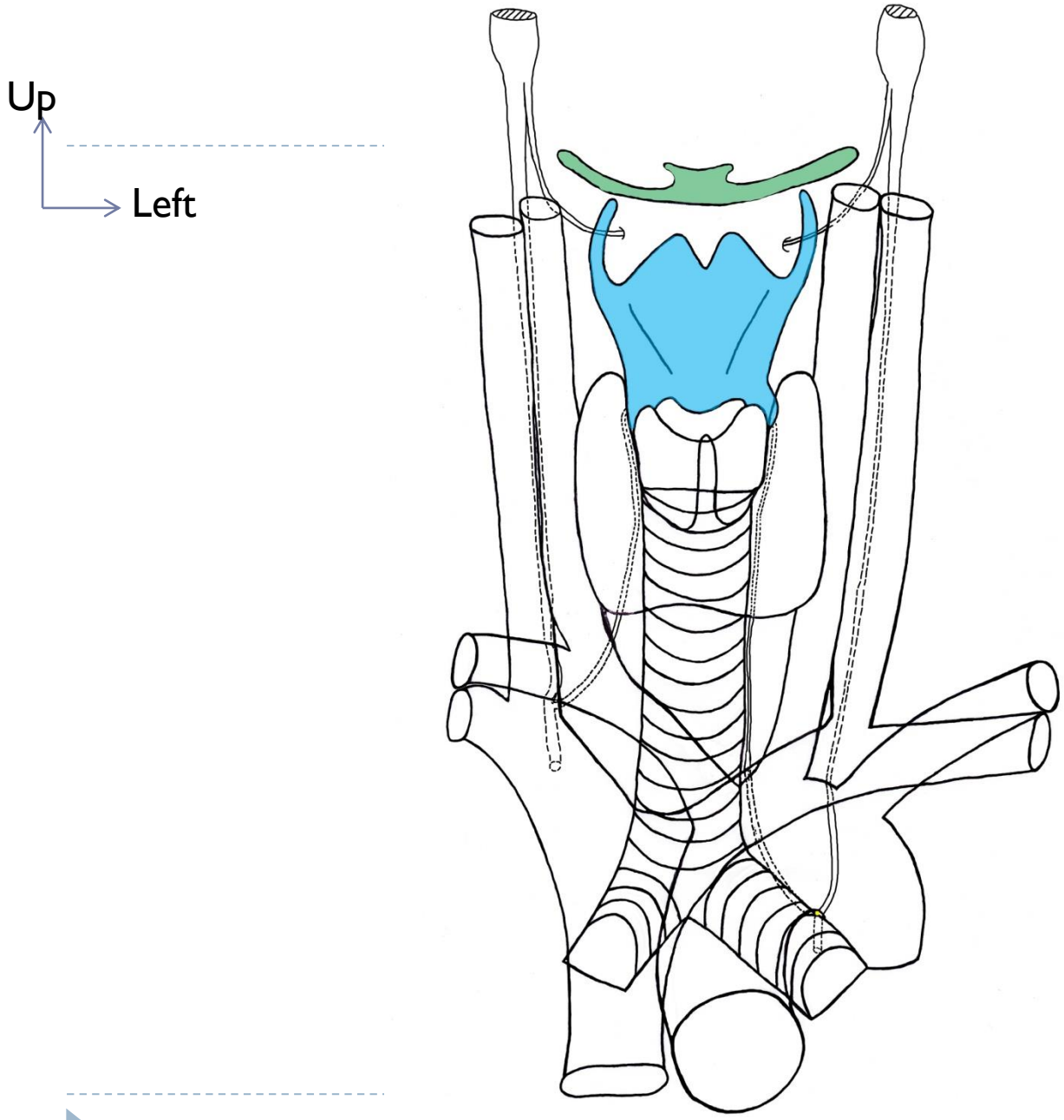
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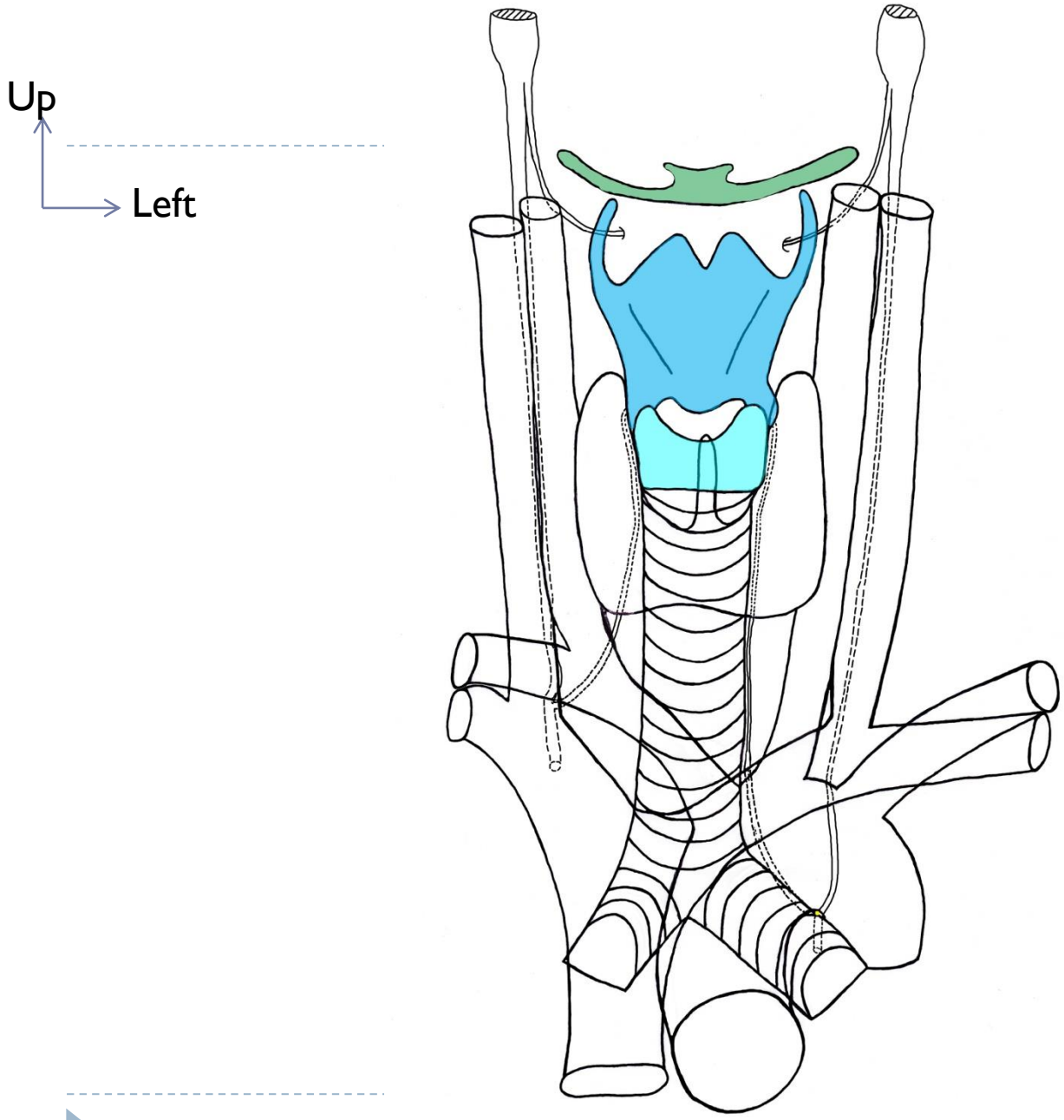
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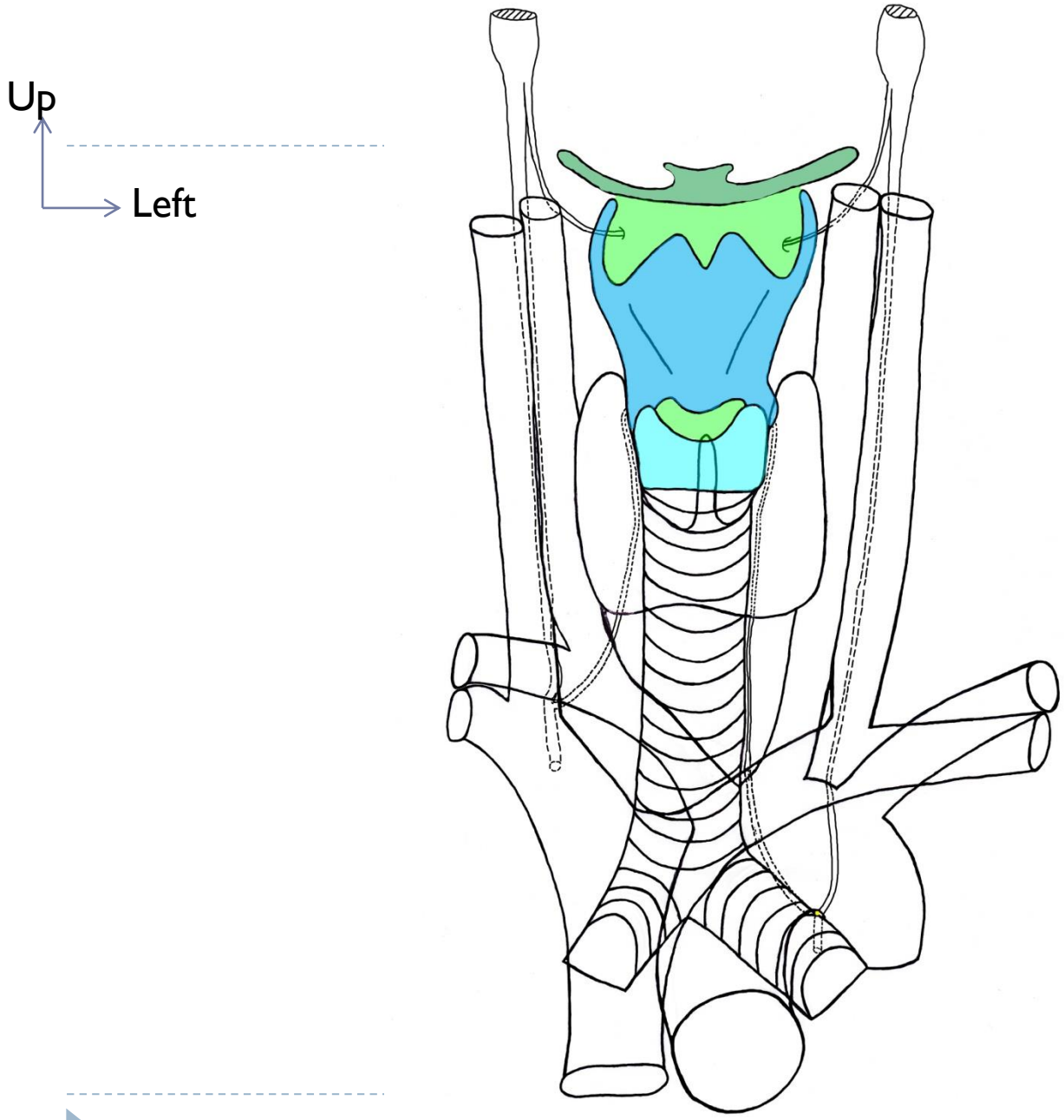
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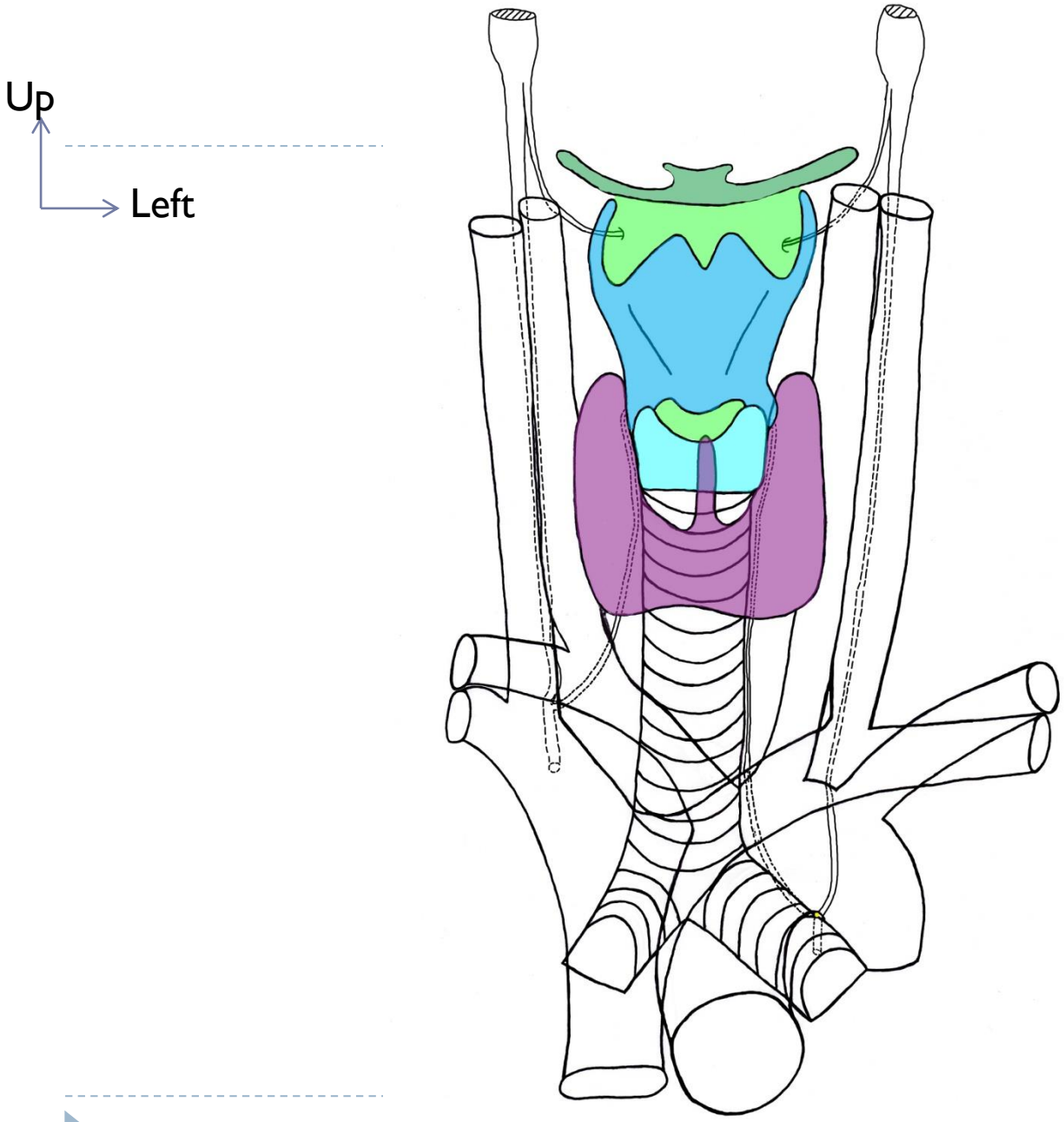
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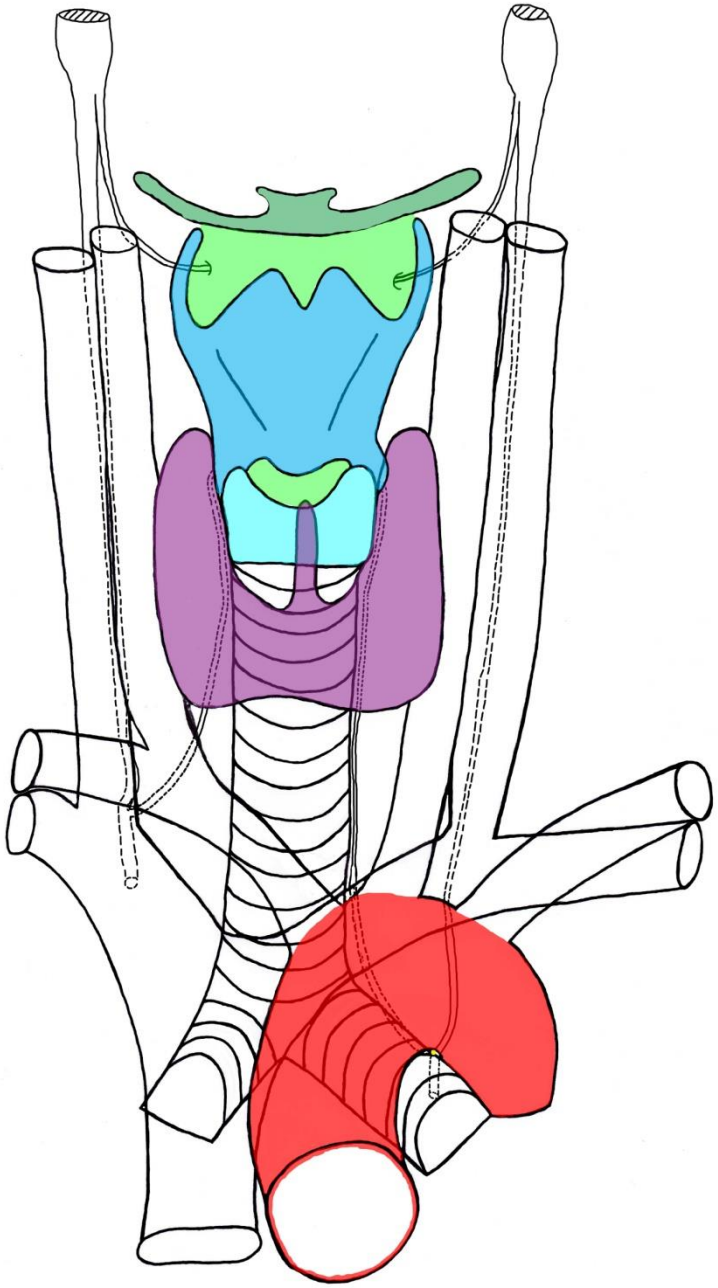

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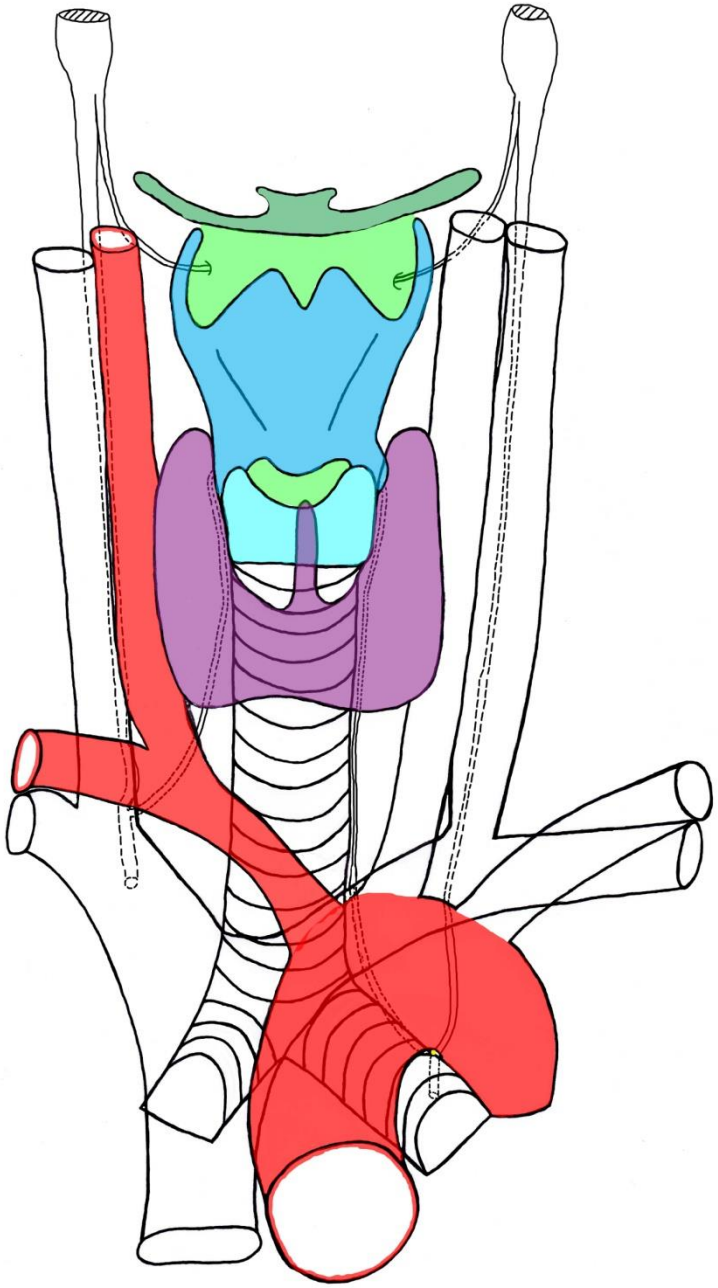

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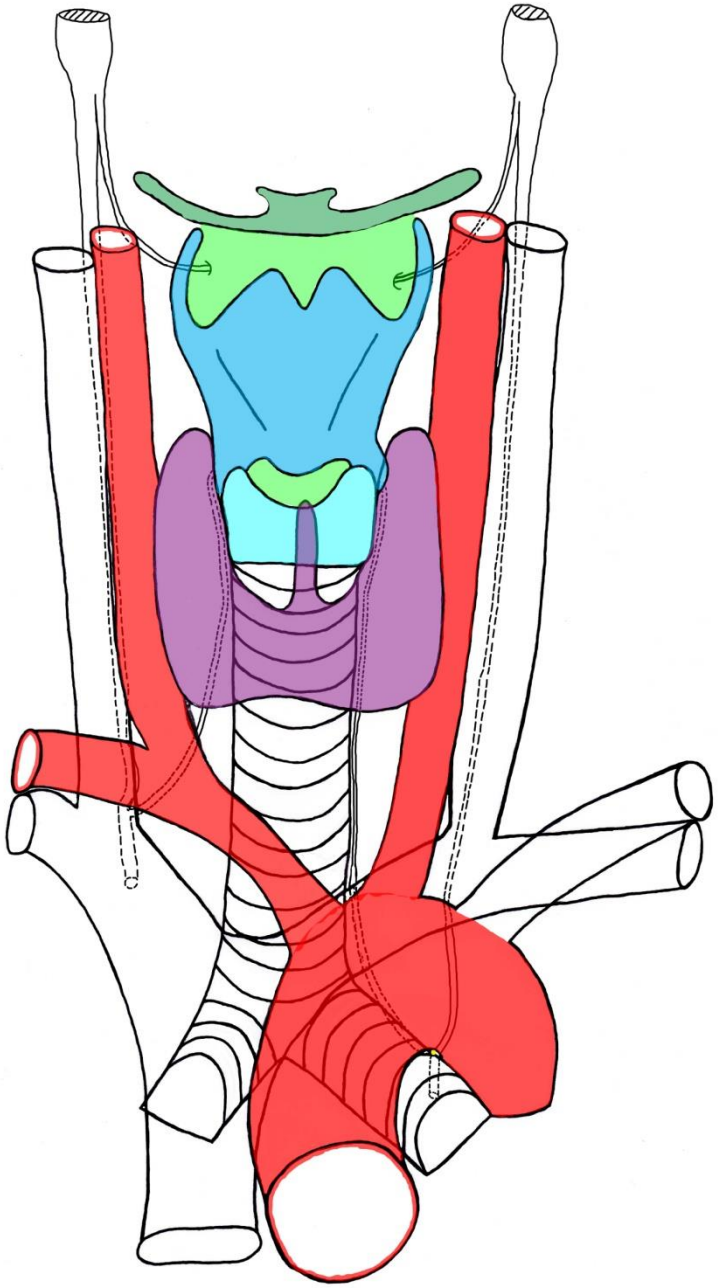

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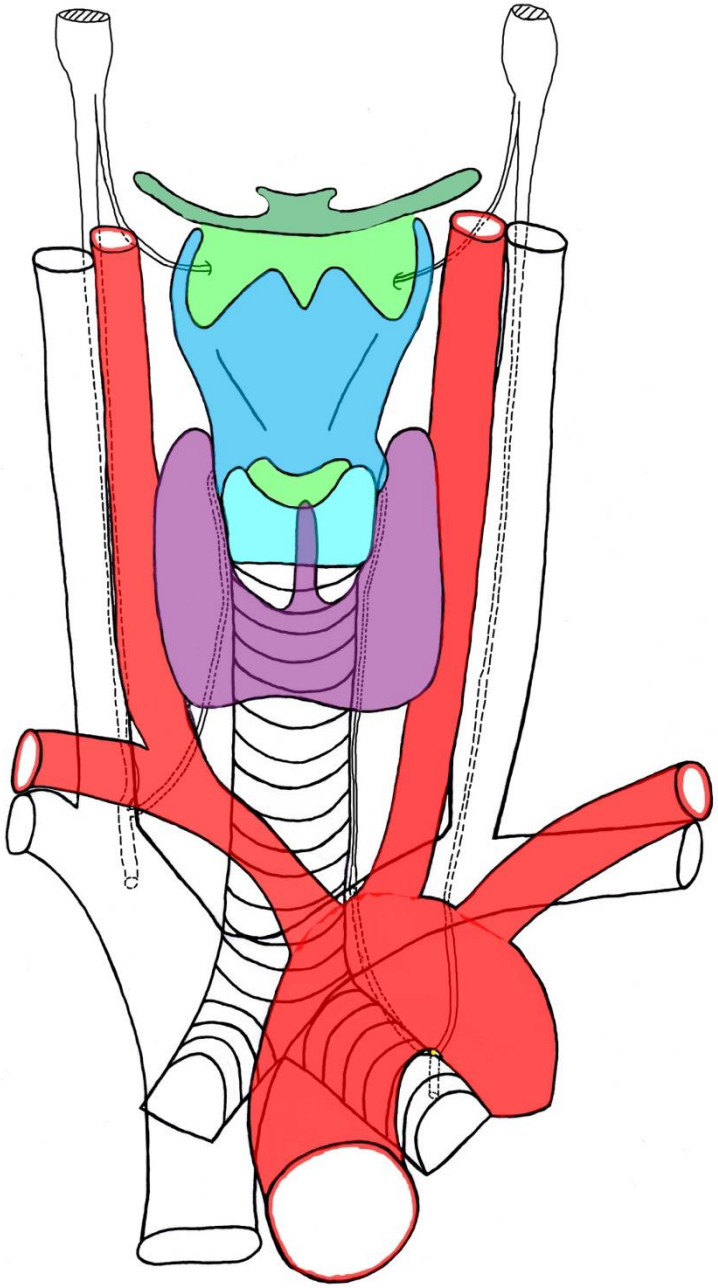

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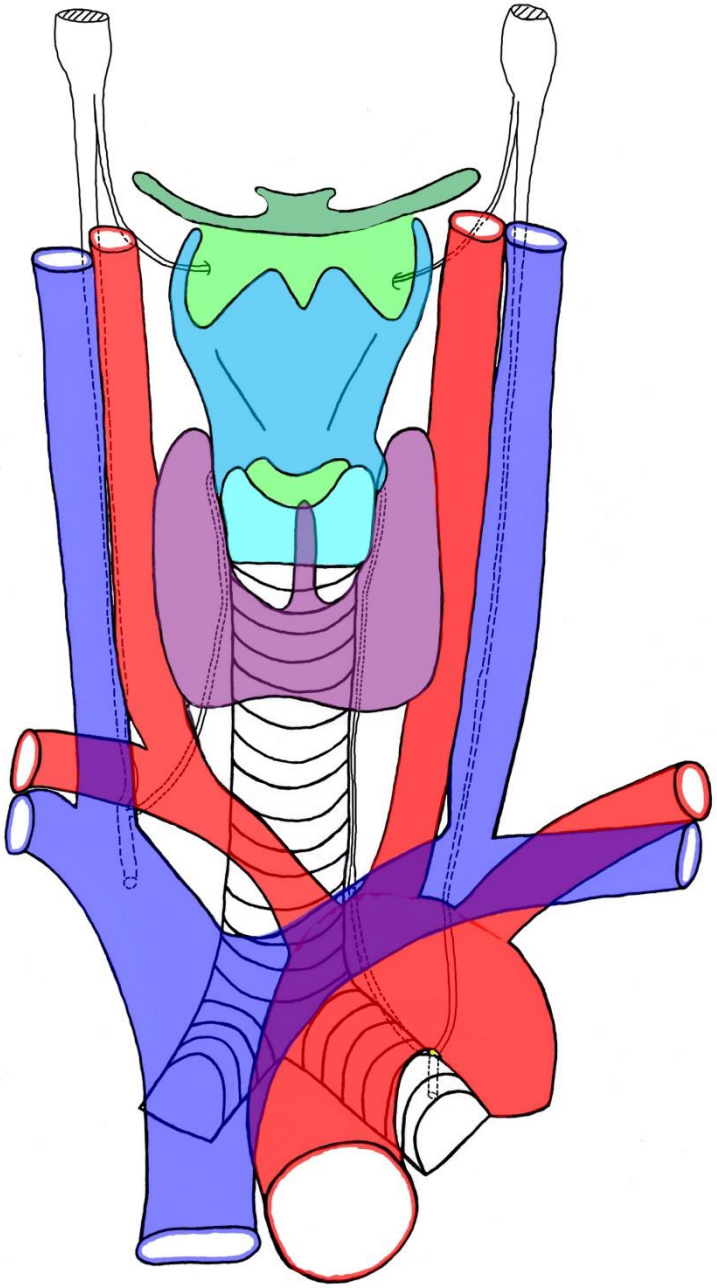

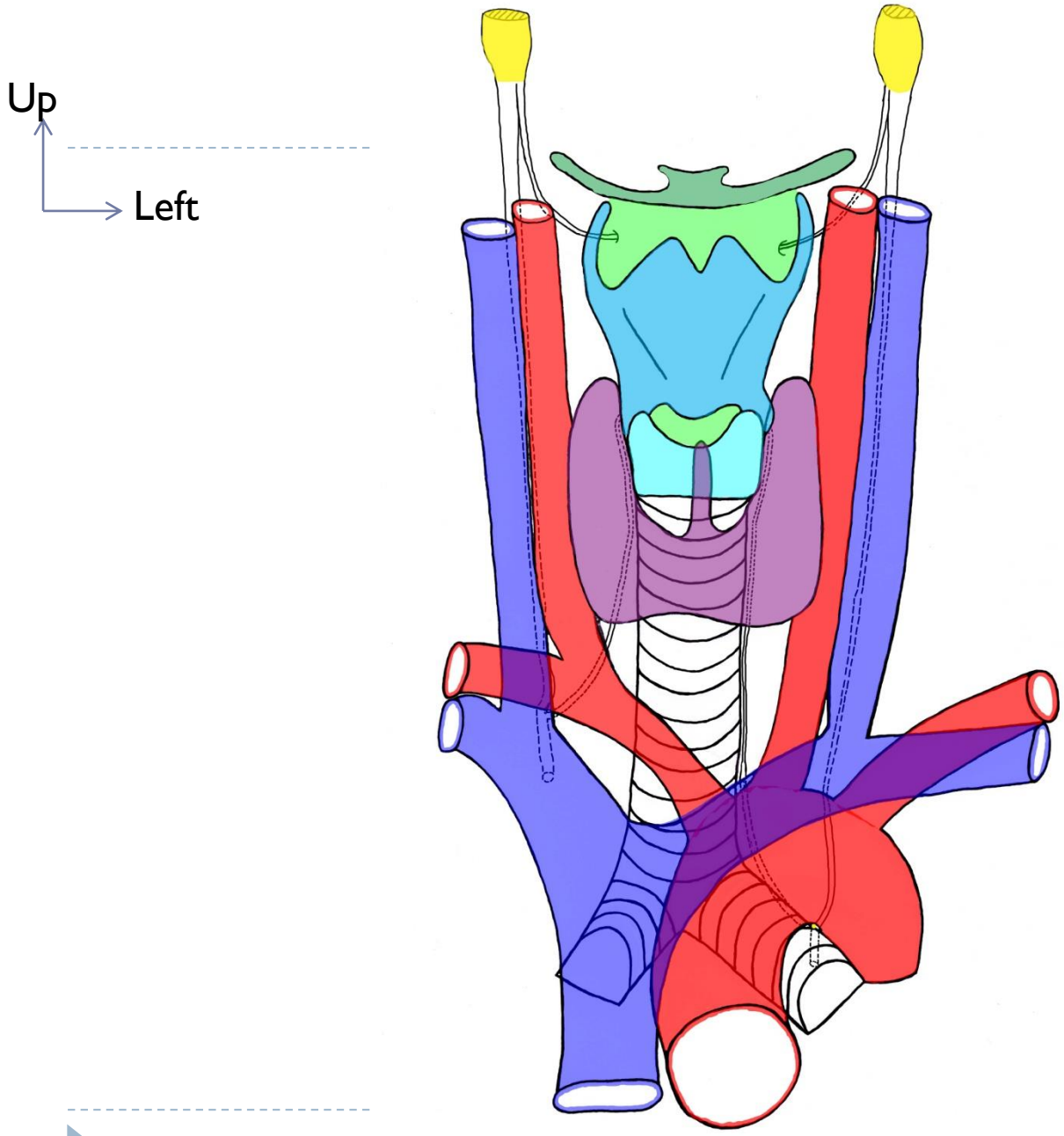
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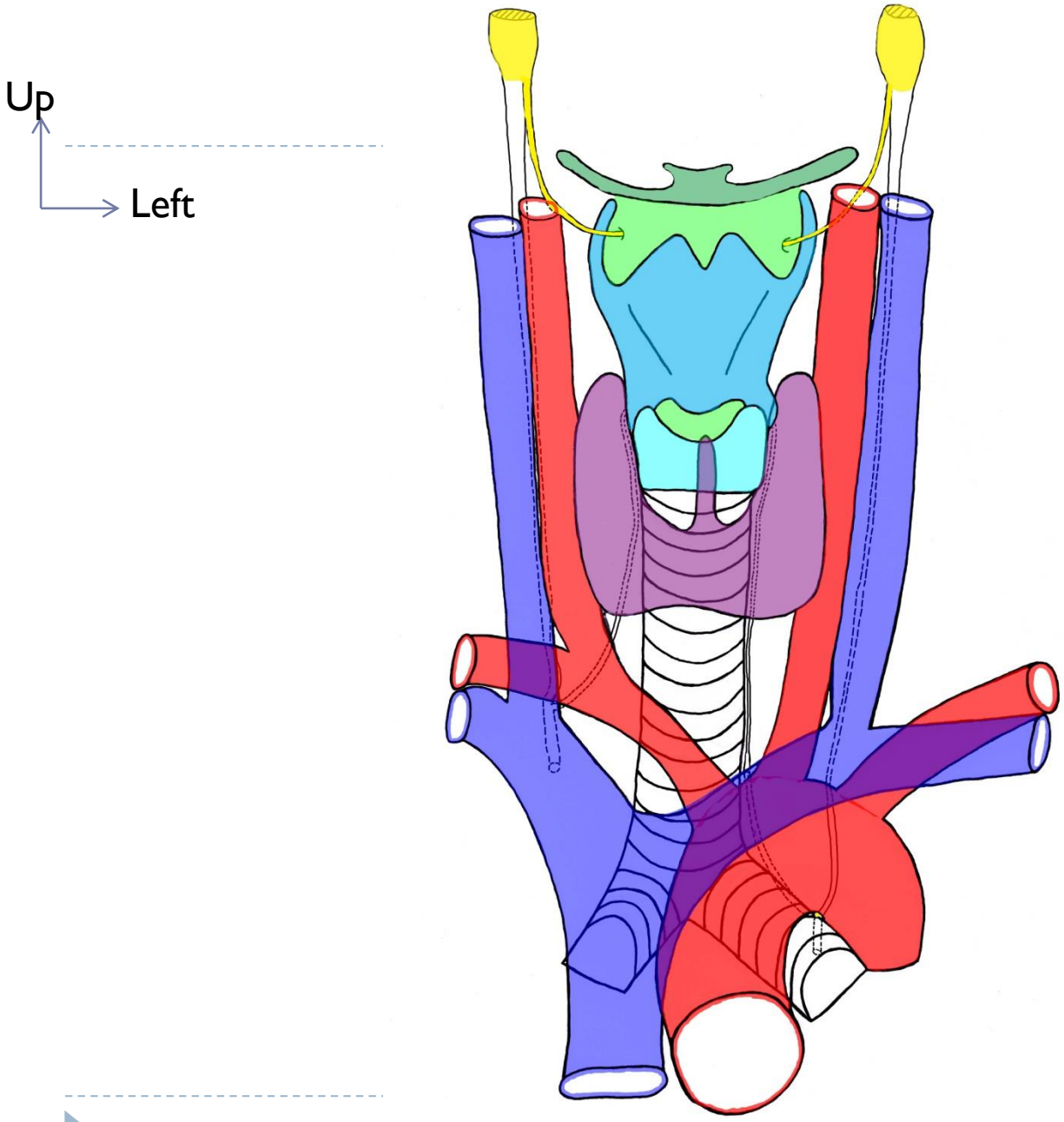
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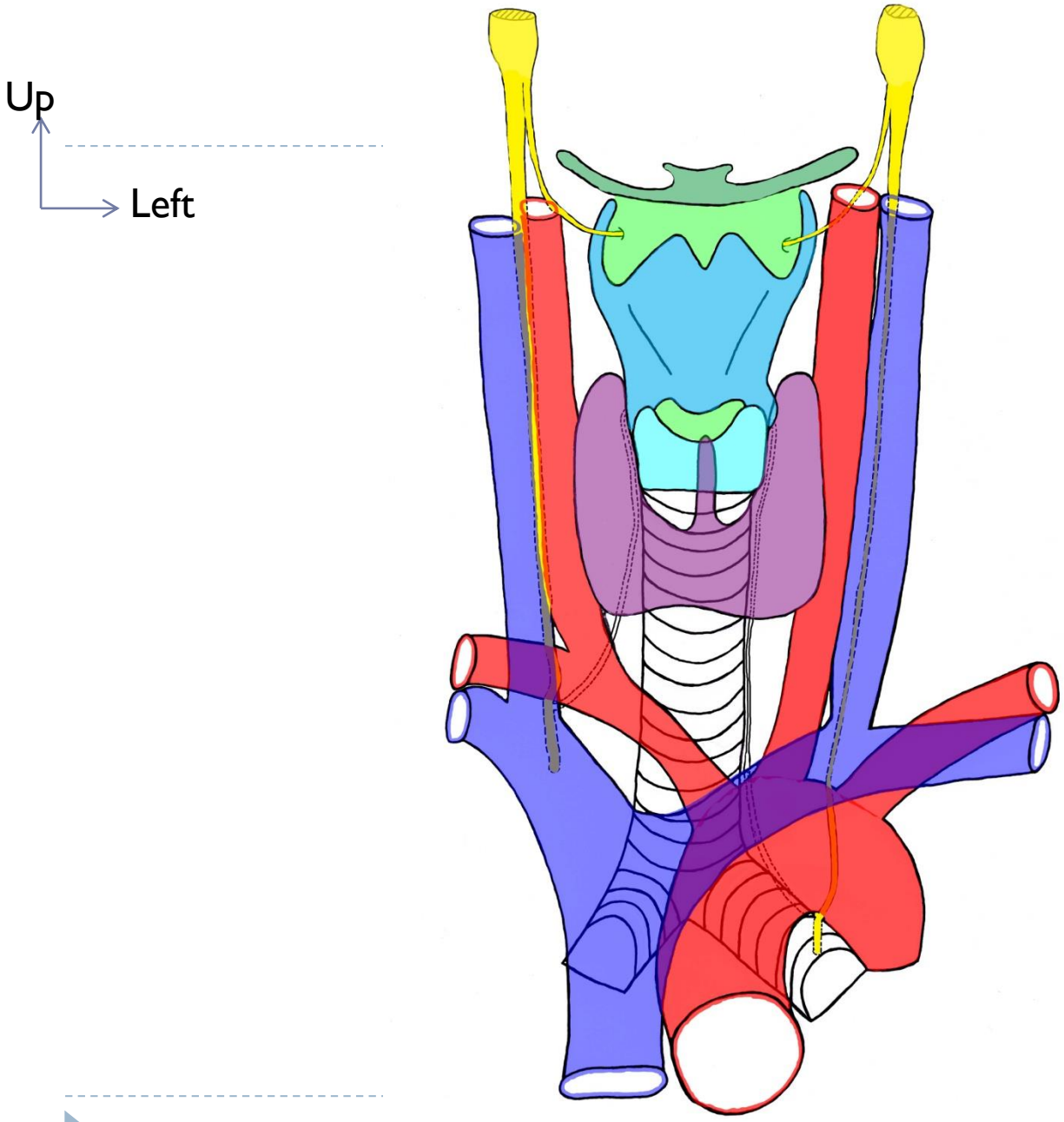
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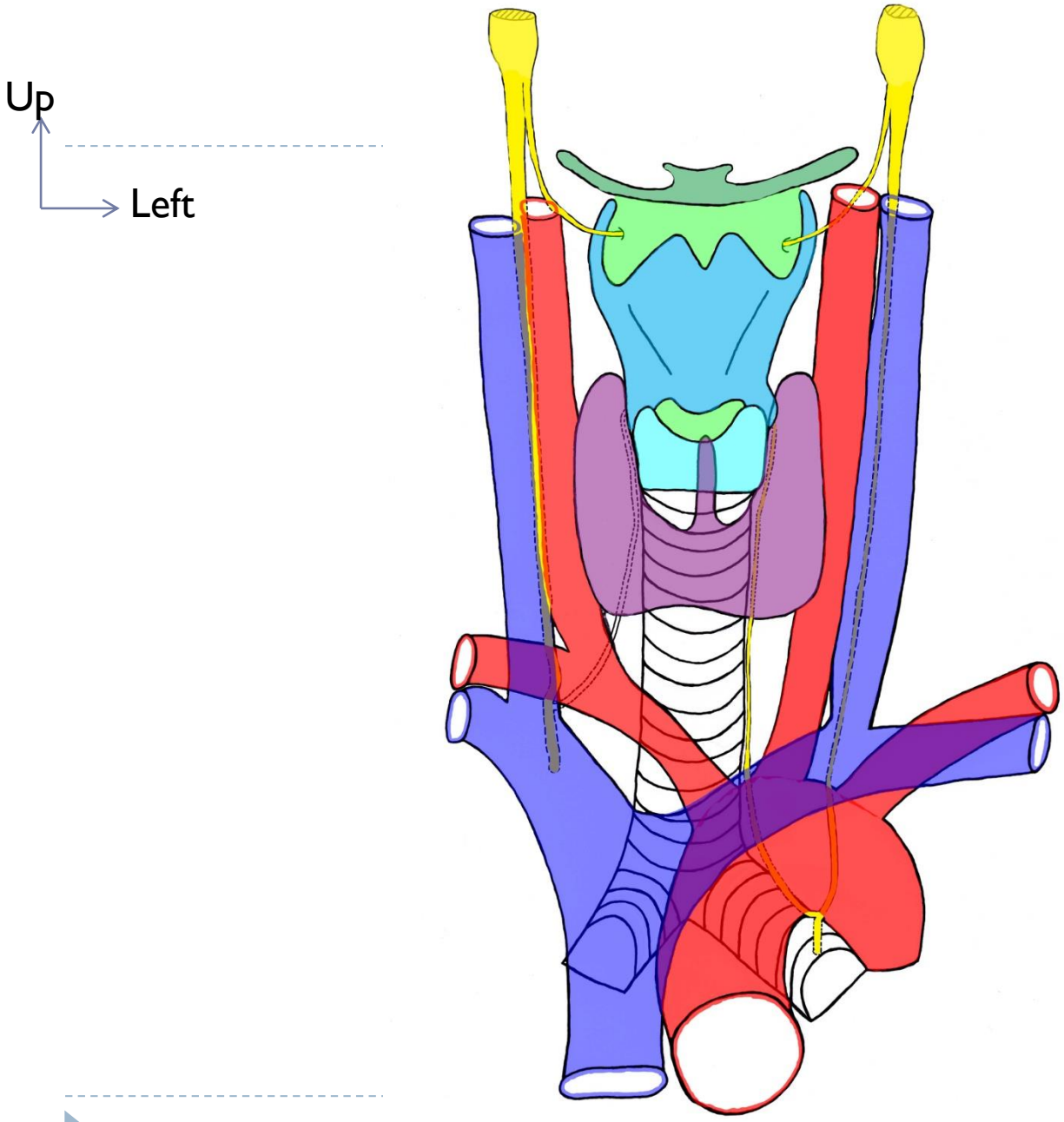
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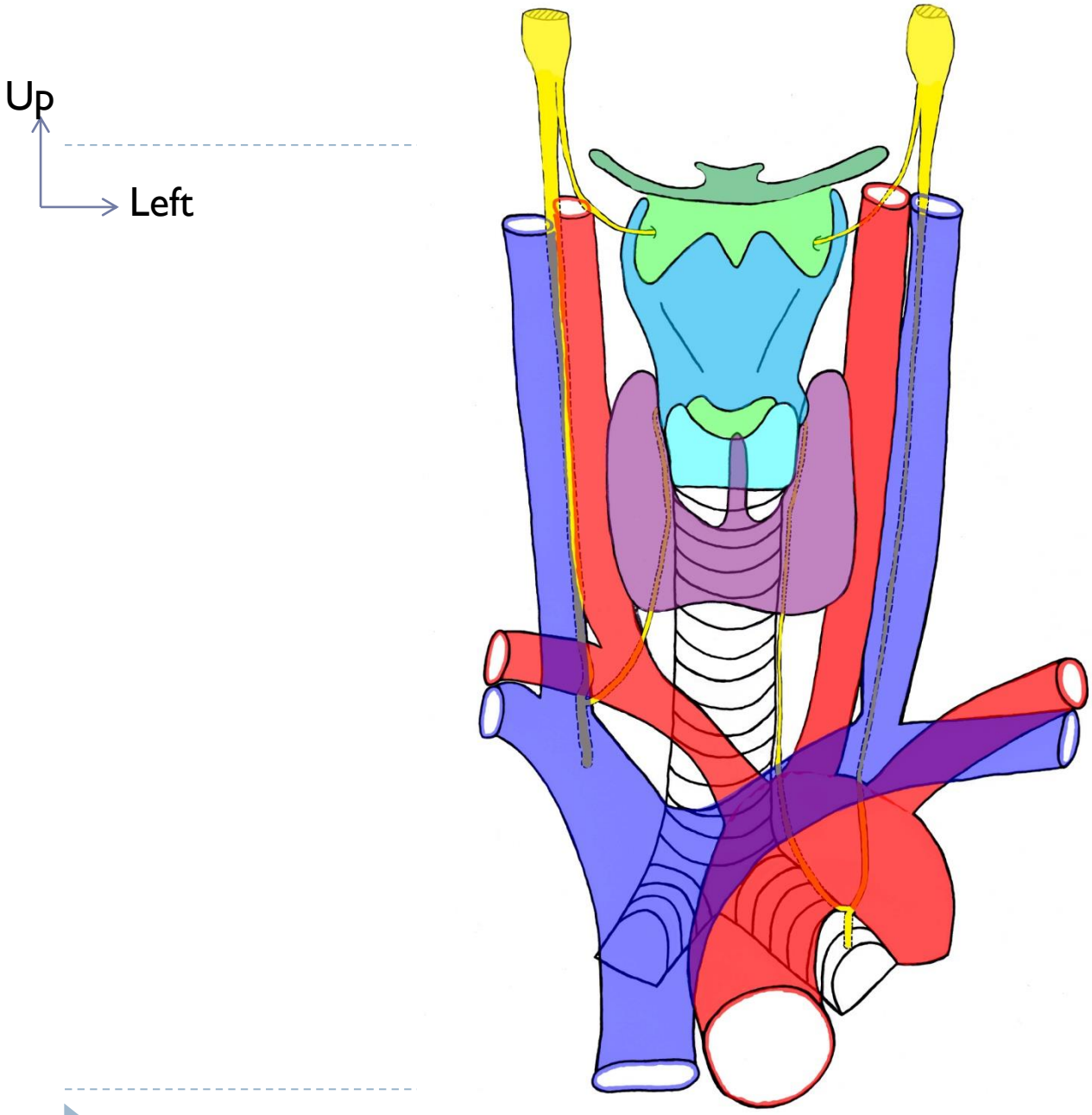
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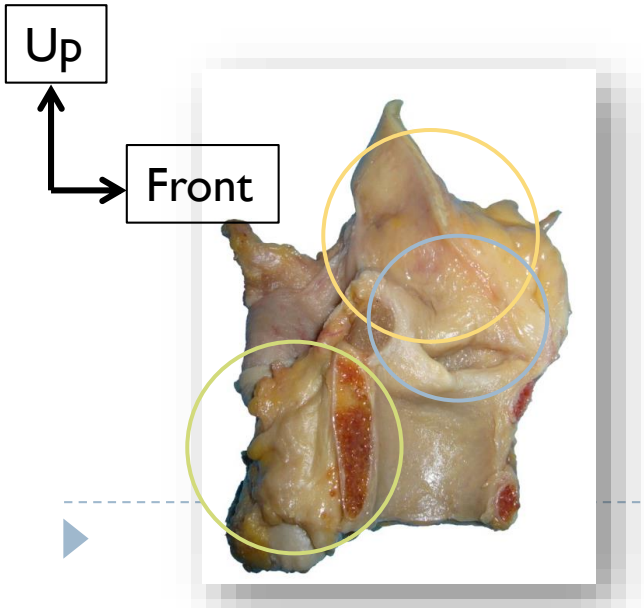
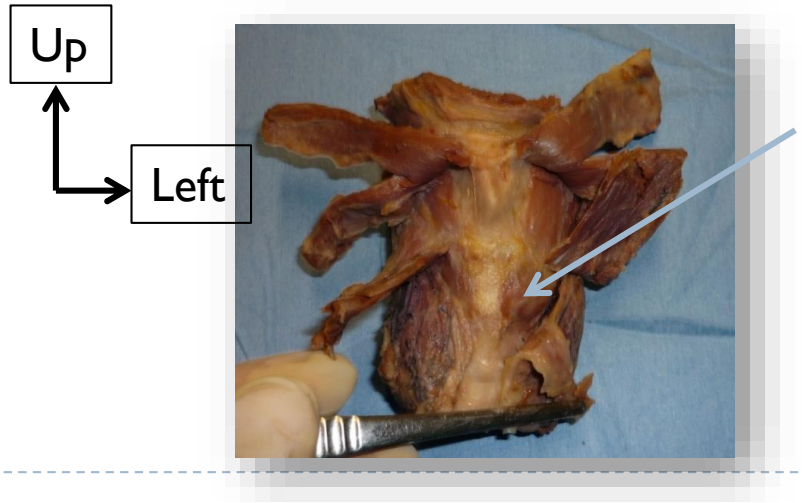
Supérior Laryngeal Nerve-Ending

Superior laryngeal nerve trunk

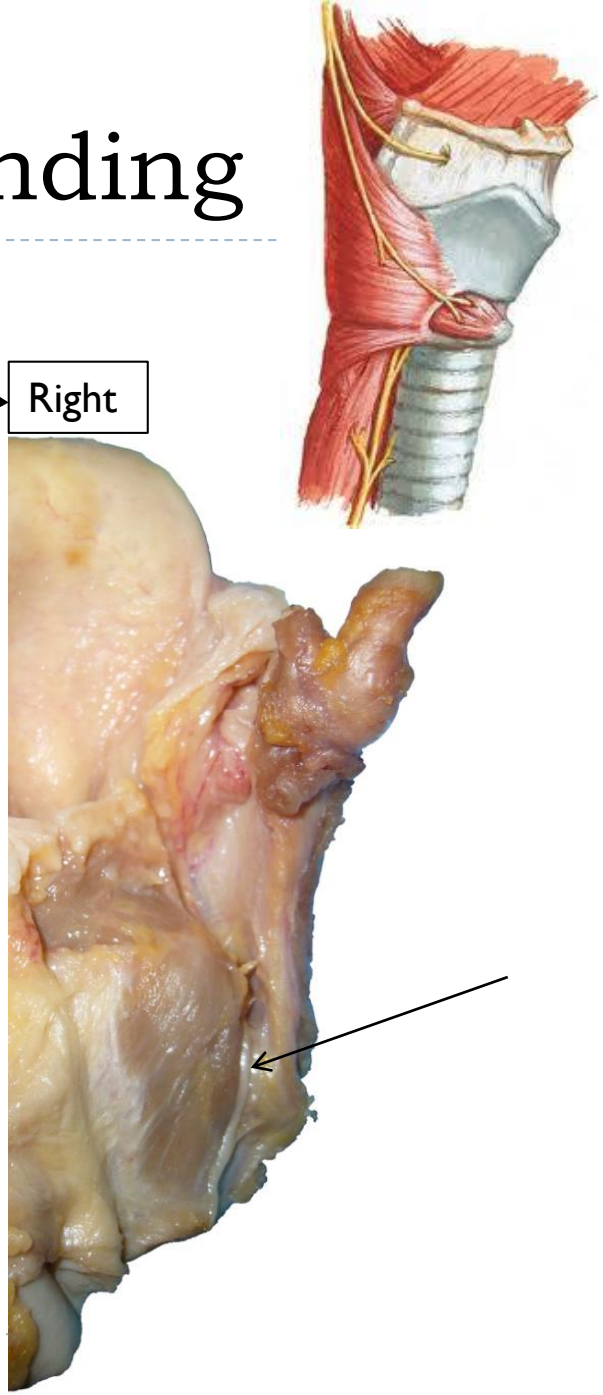
- Internal laryngeal nerve
  - Sensory
  - Laryngeal vestibule, glottic level, posterior wall
- External laryngeal nerve
  - Motricity
  - Crico-thyroïd Muscle





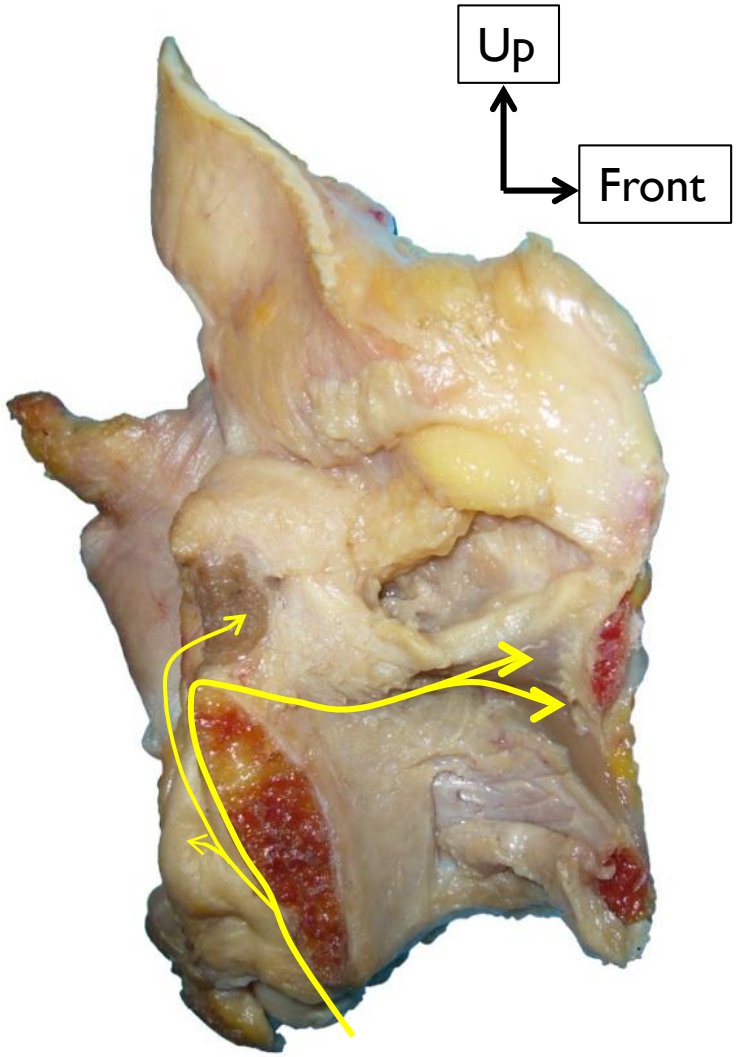
Inferior Laryngeal Nerve-Ending

- Enters in the larynx
  - Under the inferior pharyngeal constrictor
  - Behind the crico-thyroid joint
  - Under the hypopharynx mucosa



Inferior Laryngeal Nerve-Ending

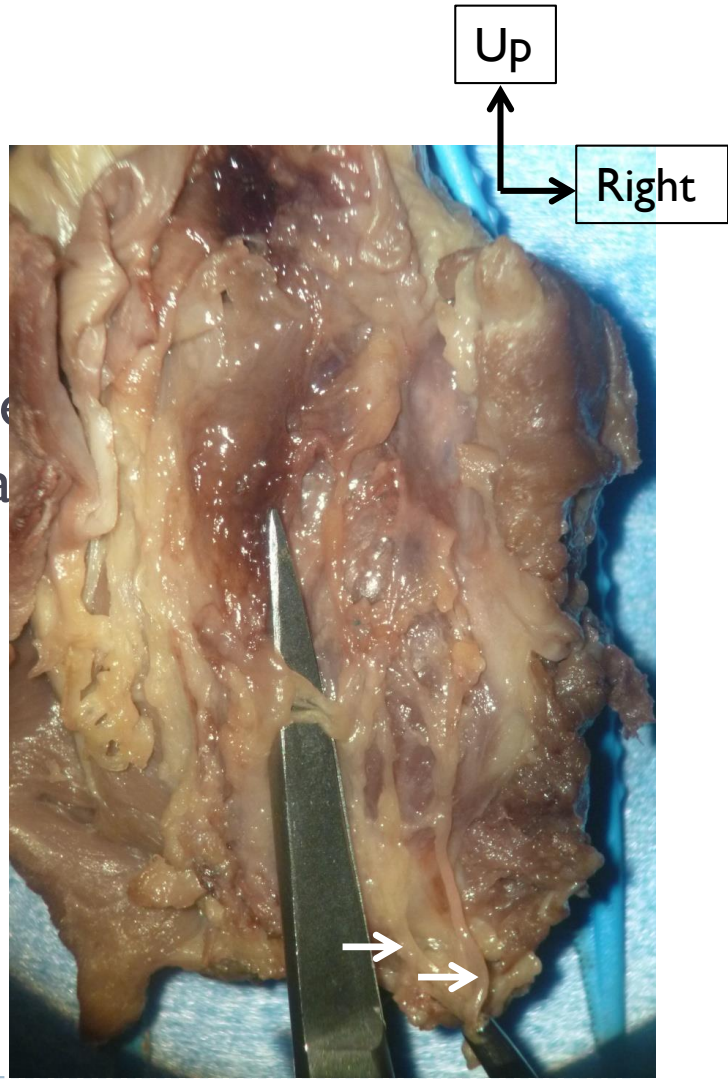
- Motor nervous branches
  - For all the intrinsic laryngeal muscles
  - EXCEPT crico-thyroid muscle



Inferior Laryngeal Nerve-Ending

2 Terminal branches

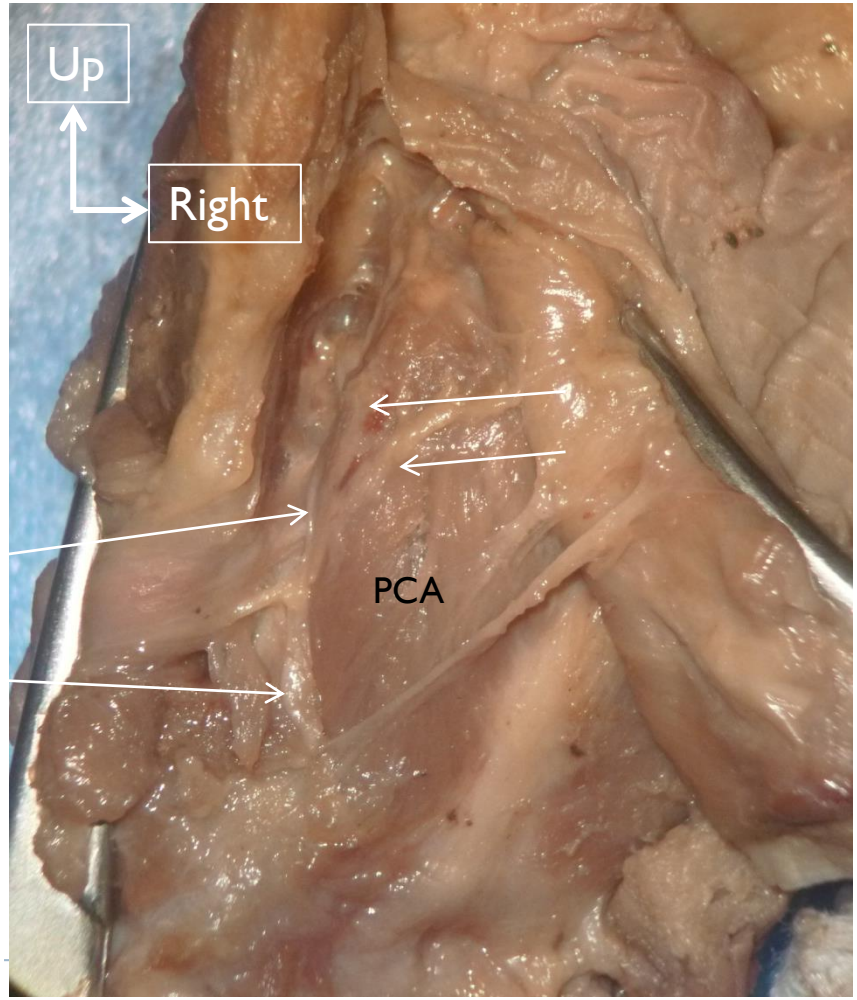
- Posterior
  - Runs on the posterior aspect of the PCA, under the pharyngeal mucosa
  - Communication with the internal laryngeal nerve
    - Galien ansa



Inferior Laryngeal Nerve-Ending

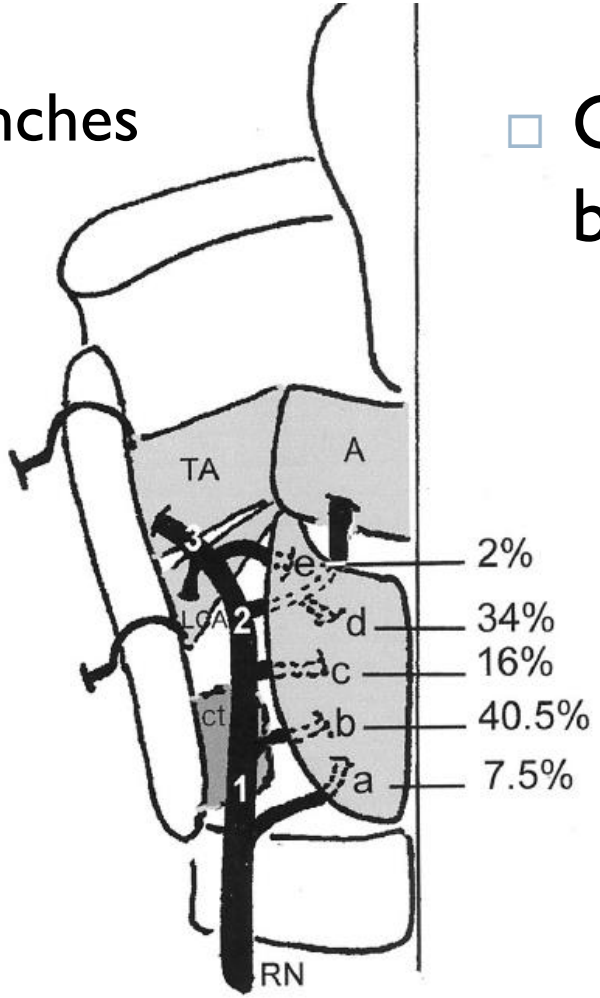
2 Terminal branches

- Anterior
  - Motor Innervation of the intrinsic muscles
  - Vertical segment: behind the crico-thyroid joint
  - Genu: Anterior curve, above the joint
  - Oblique segment, laterally to LCA muscle



Inferior laryngeal Nerve : variability of the terminal branches

- Number of branches
  - 1 branch=7.3%
  - 2 branches=42.7%
  - 3 branches=34%
  - 4 branches=10.7%
  - 5 branches=4.7%
  - 6 branches: 0.6%

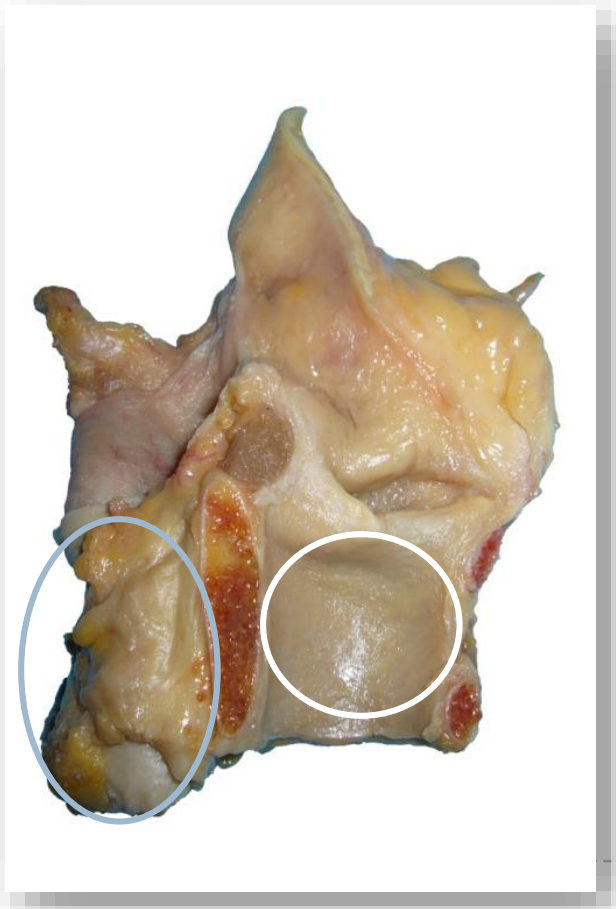


- Origins of the PCA branches
  - A:vertical segment under CT joint
  - b: vertical segment behind CT joint
  - c: vertical segment above CT joint
  - d=genu, common origin with IA nerve branch
  - e=oblique segment, between the IA and LCA branches

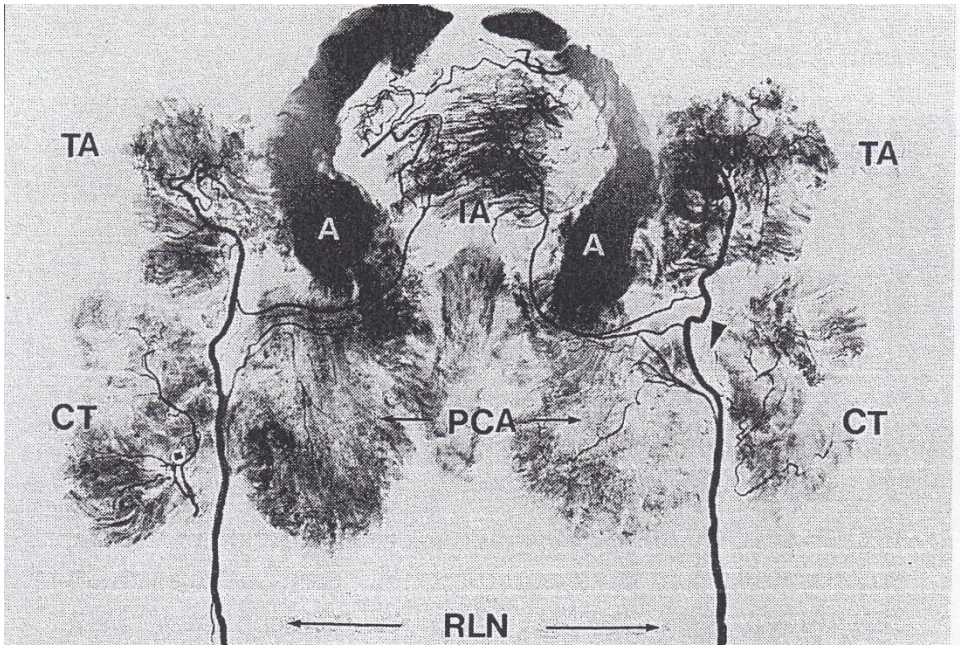
Maranillo E, León X, Ibañez M, Orús C, Quer M, Sañudo JR.
Variability of the nerve supply patterns of the human posterior cricoarytenoid muscle. Laryngoscope. 2003 Apr;113(4):602-6.

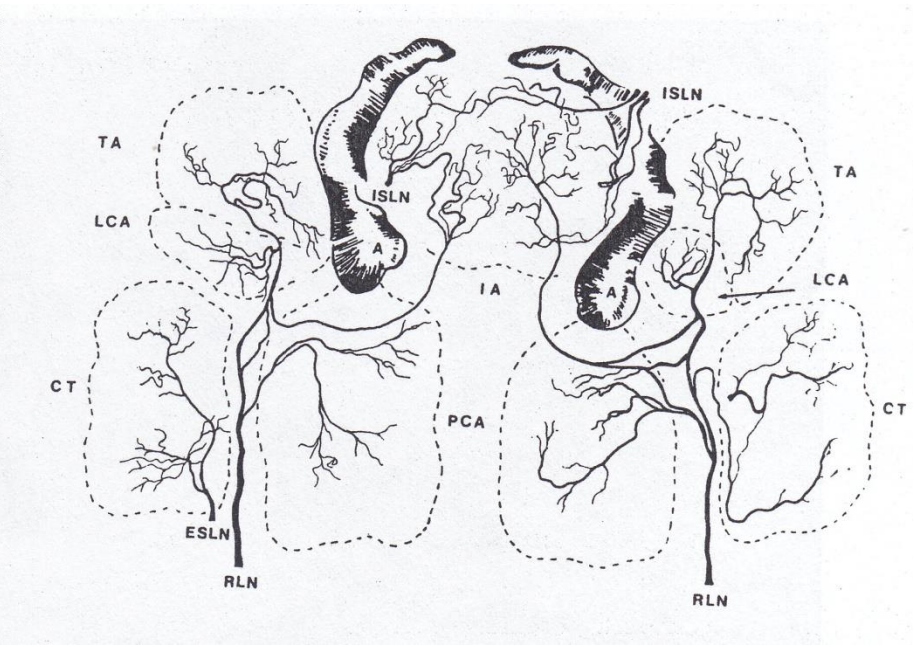
Inferior laryngeal nerve-Ending

- Sensory branches
  - Piriform sinus
  - Subglottic space



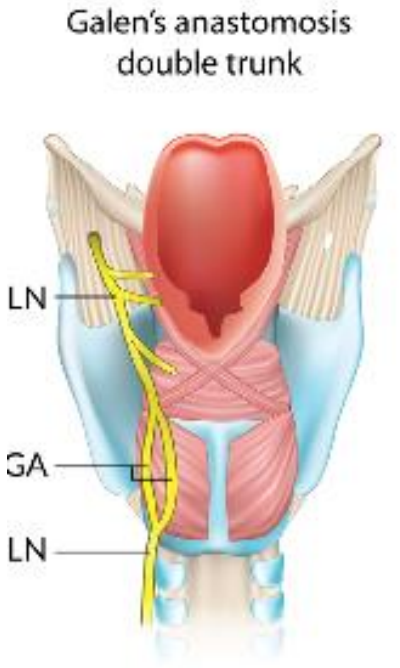
Communications between ILN and SLN

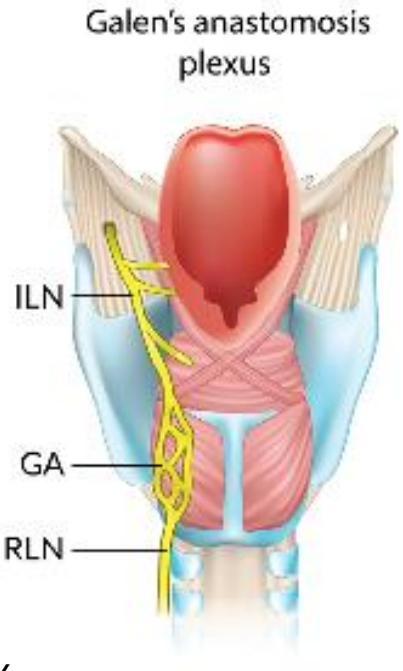




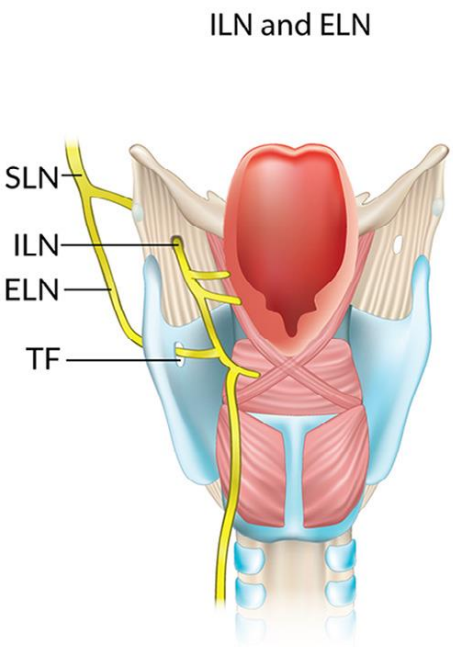
- Sanders I, Wu BL, Mu L, Li Y, Biller HF.
  The innervation of the human larynx. Arch Otolaryngol Head Neck Surg. 1993 Sep;119(9):934-9.

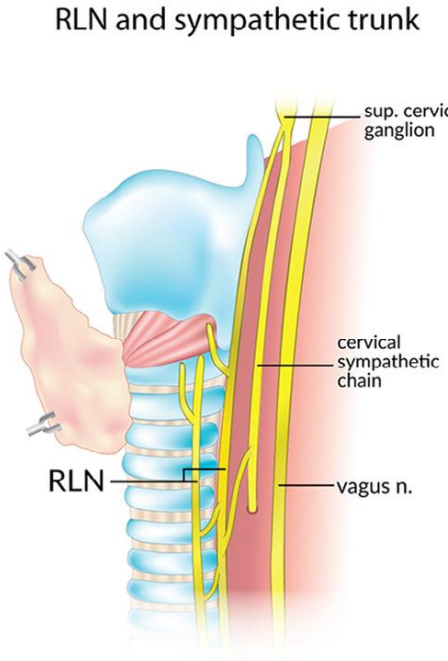
Communications between ILN and SLN





90%

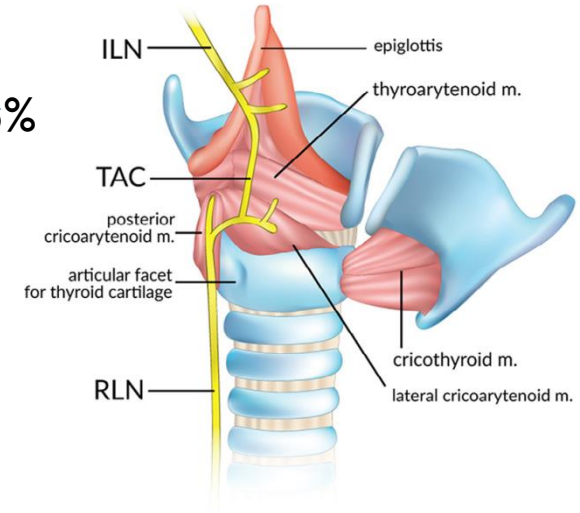




Henry M, Pekala PA, Sanna B, Vikse J, Sanna S, Saganiak K, Tomaszewska IM, Tubbs RS, Tomaszewski KA. The Anastomoses of the Recurrent Laryngeal Nerve in the Larynx: A Meta-Analysis and Systematic Review. J Voice, 2017;Vol. 31 (4), 495–503.

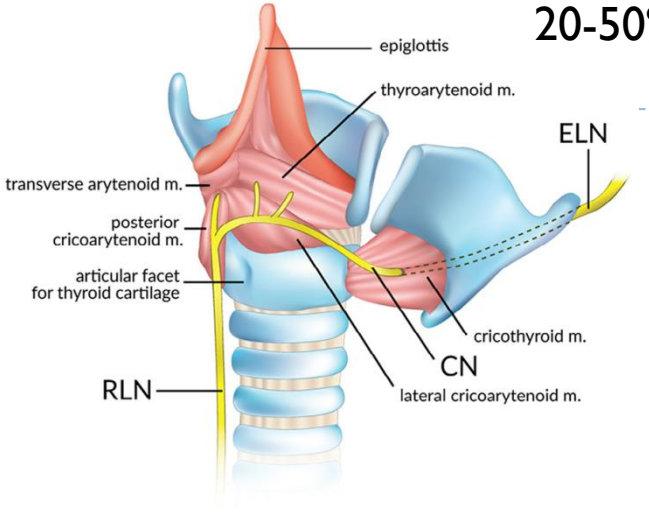
Thyroarythenoid communication

8-15%



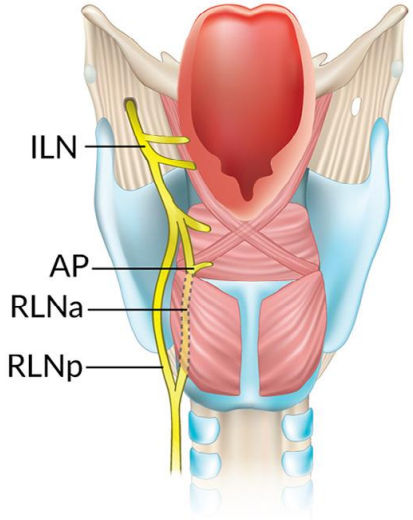
Communication between ELN and RLN

20-50%



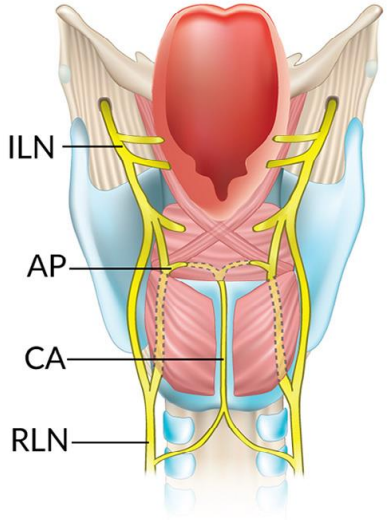
Arytenoid plexus

70%



Cricoid communication

20%



Henry M, Pekala PA, Sanna B, Vikse J, Sanna S, Saganiak K, Tomaszewska IM, Tubbs RS, Tomaszewski KA. The Anastomoses of the Recurrent Laryngeal Nerve in the Larynx: A Meta-Analysis and Systematic Review. J Voice, 2017;Vol. 31 (4), 495–503.