New Methods of Respiratory Monitoring

Technical and Clinical Challenges

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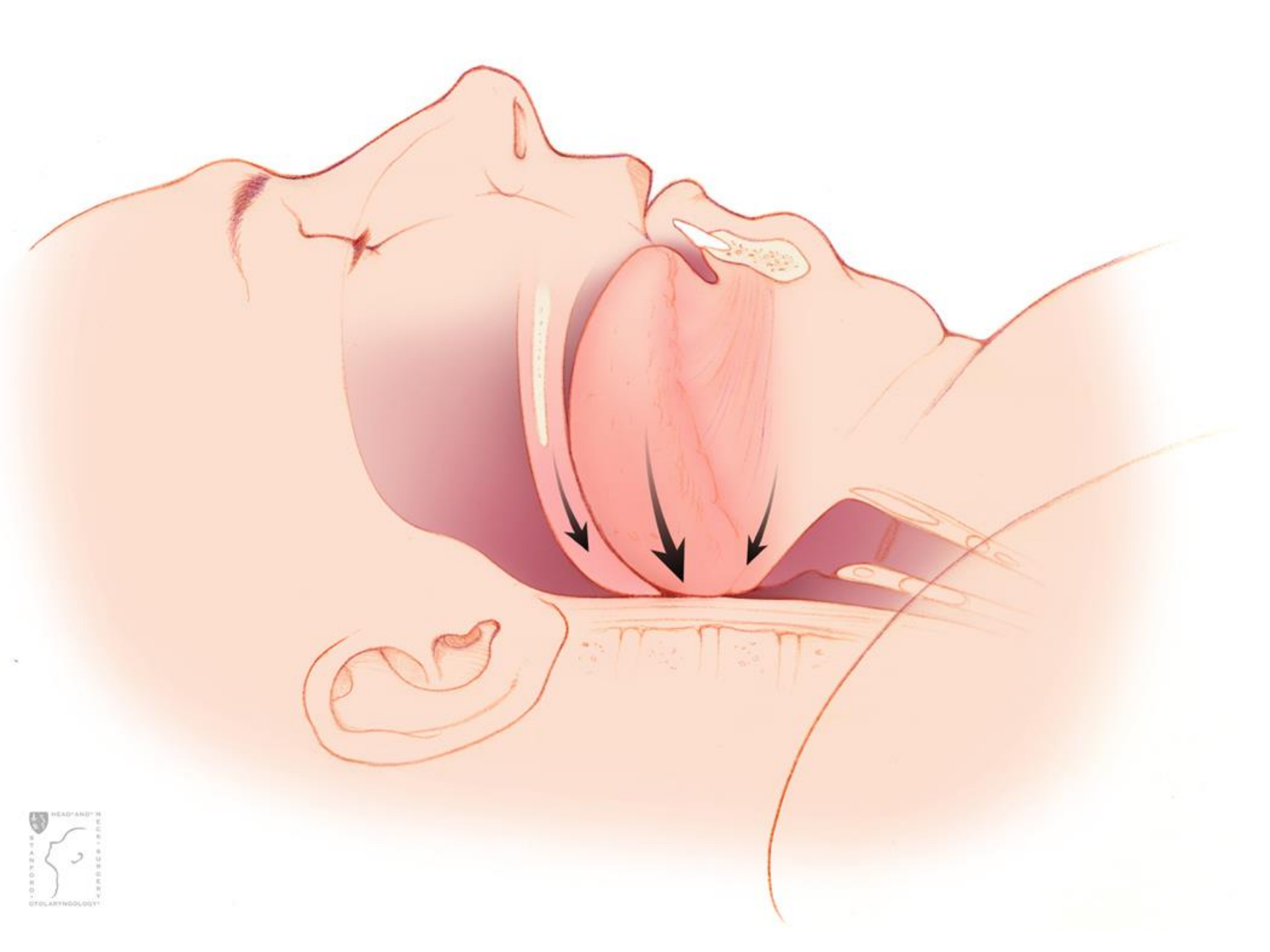
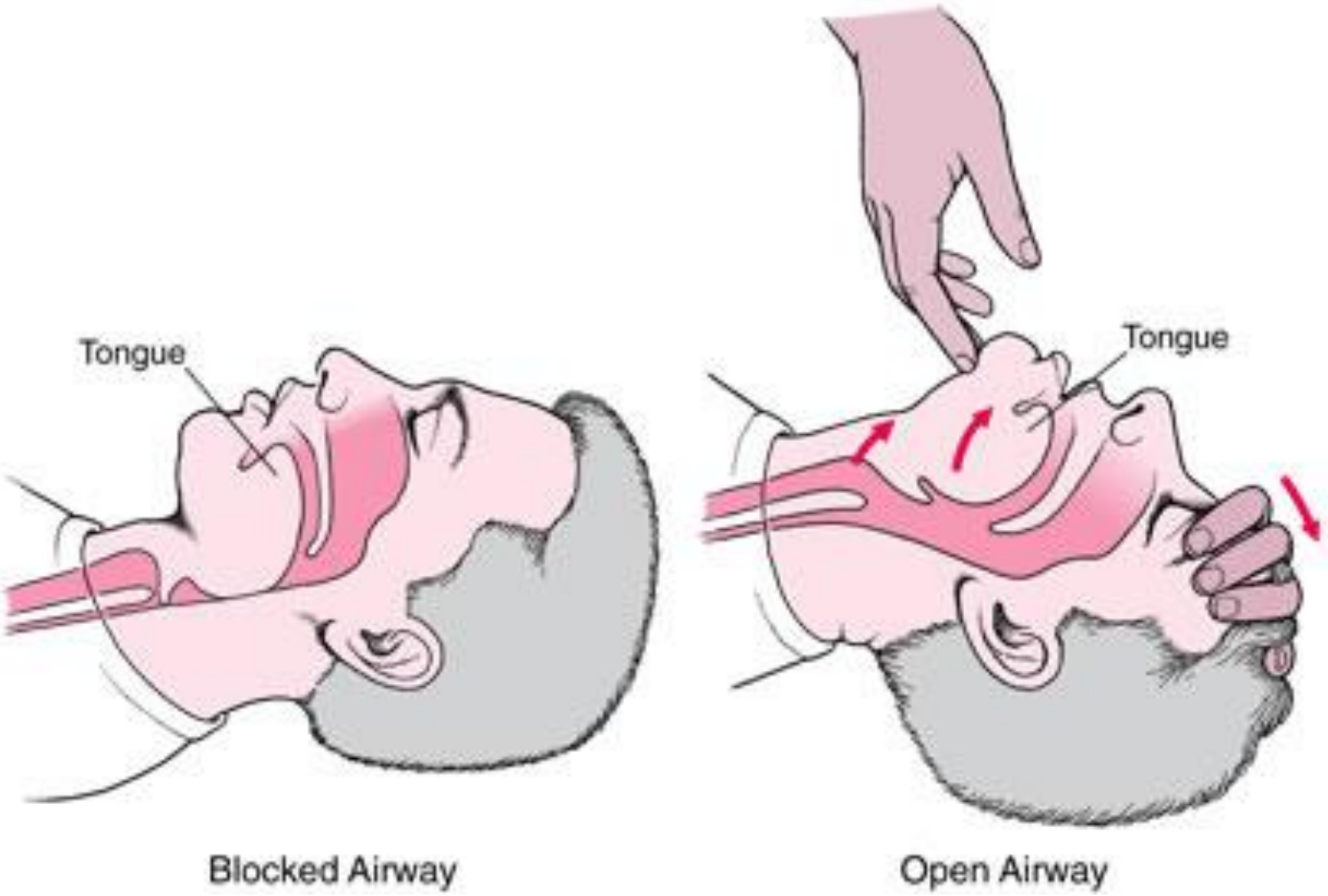
The Respiratory Monitoring Problem

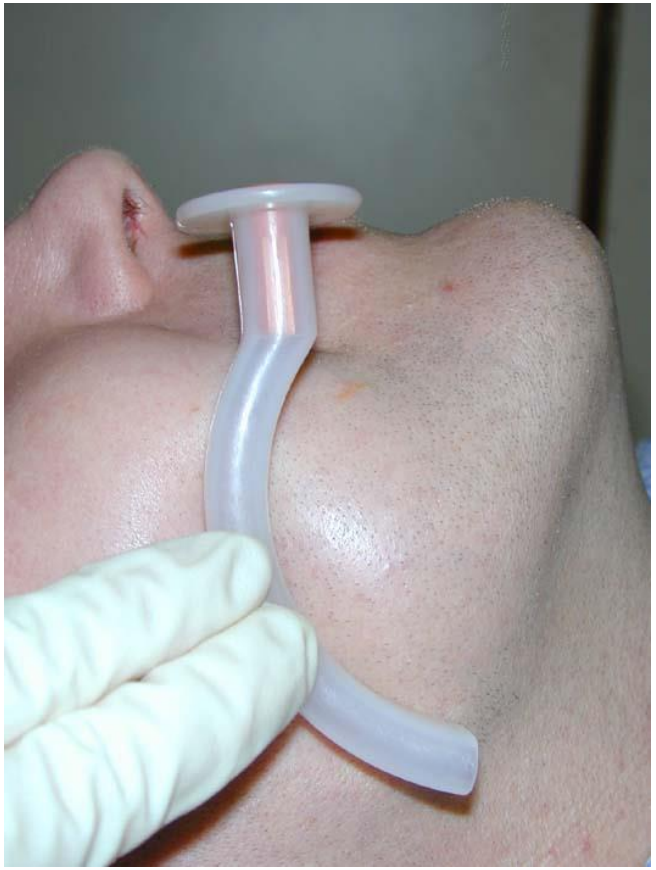
- An increased emphasis on postoperative pain control has resulted in aggressive use of opiates for pain control (e.g. PCA morphine).
- Patients with obesity or obstructive sleep apnea are increasingly common in the USA and elsewhere.
- Existing methods of respiratory monitoring for postoperative ward patients have serious drawbacks.

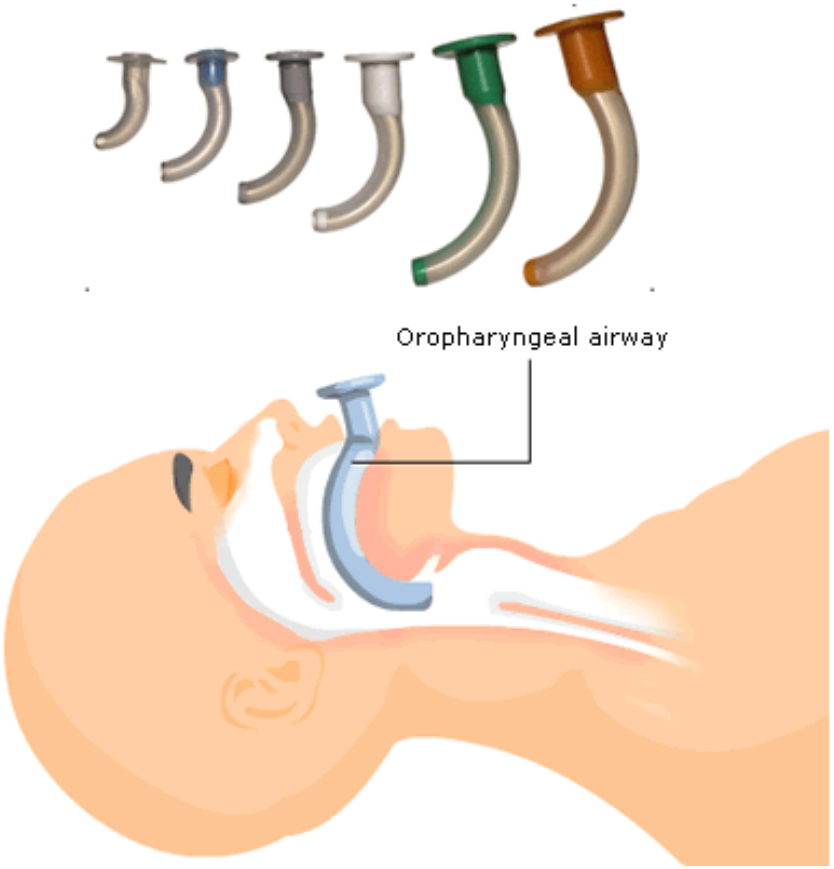
Airway Issues

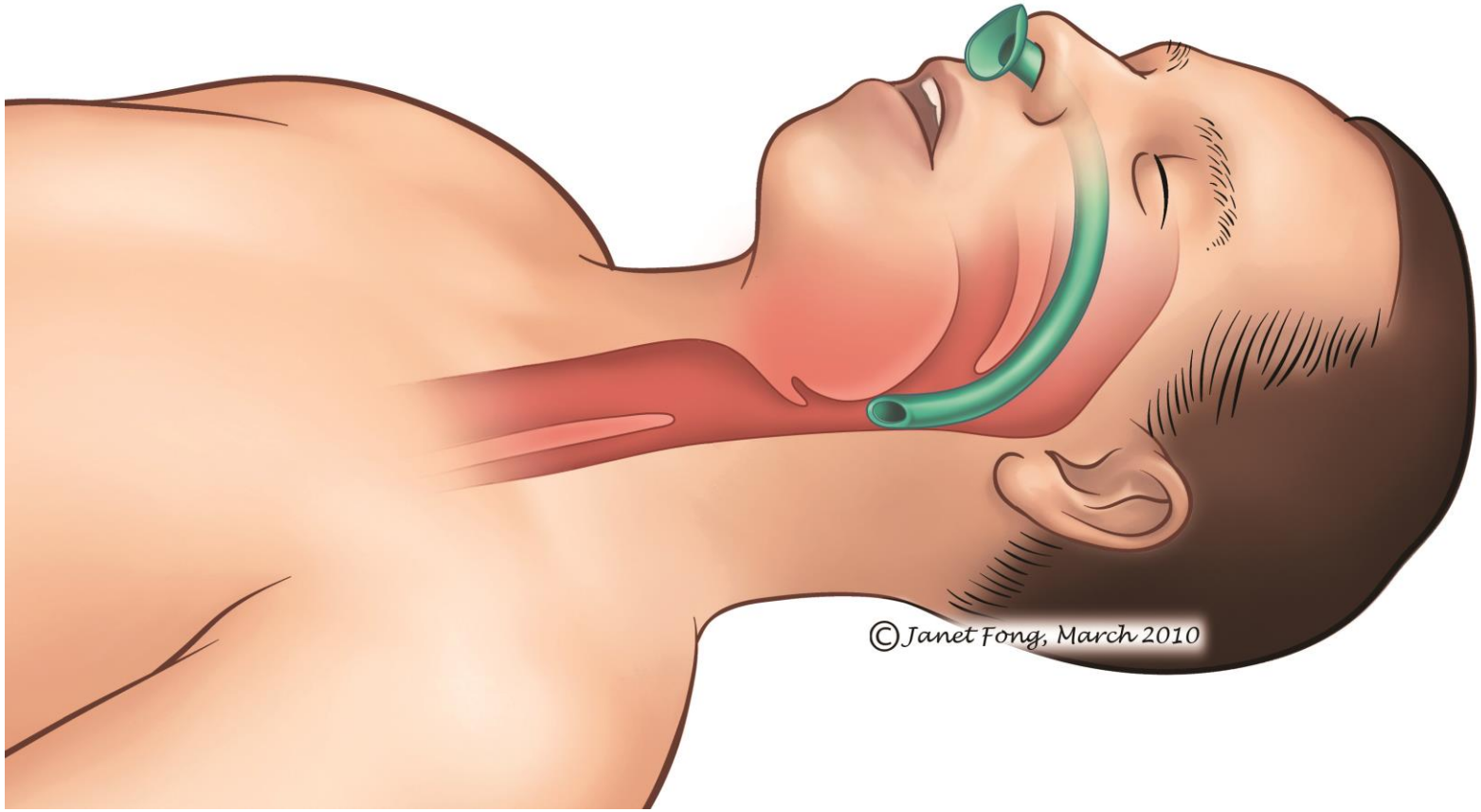
More Airway Issues


HEAD AND NECK SURGERY
STANFORD OTOLARYNGOLOGY


Tongue
Tongue
Blocked Airway
Open Airway




Oropharyngeal airway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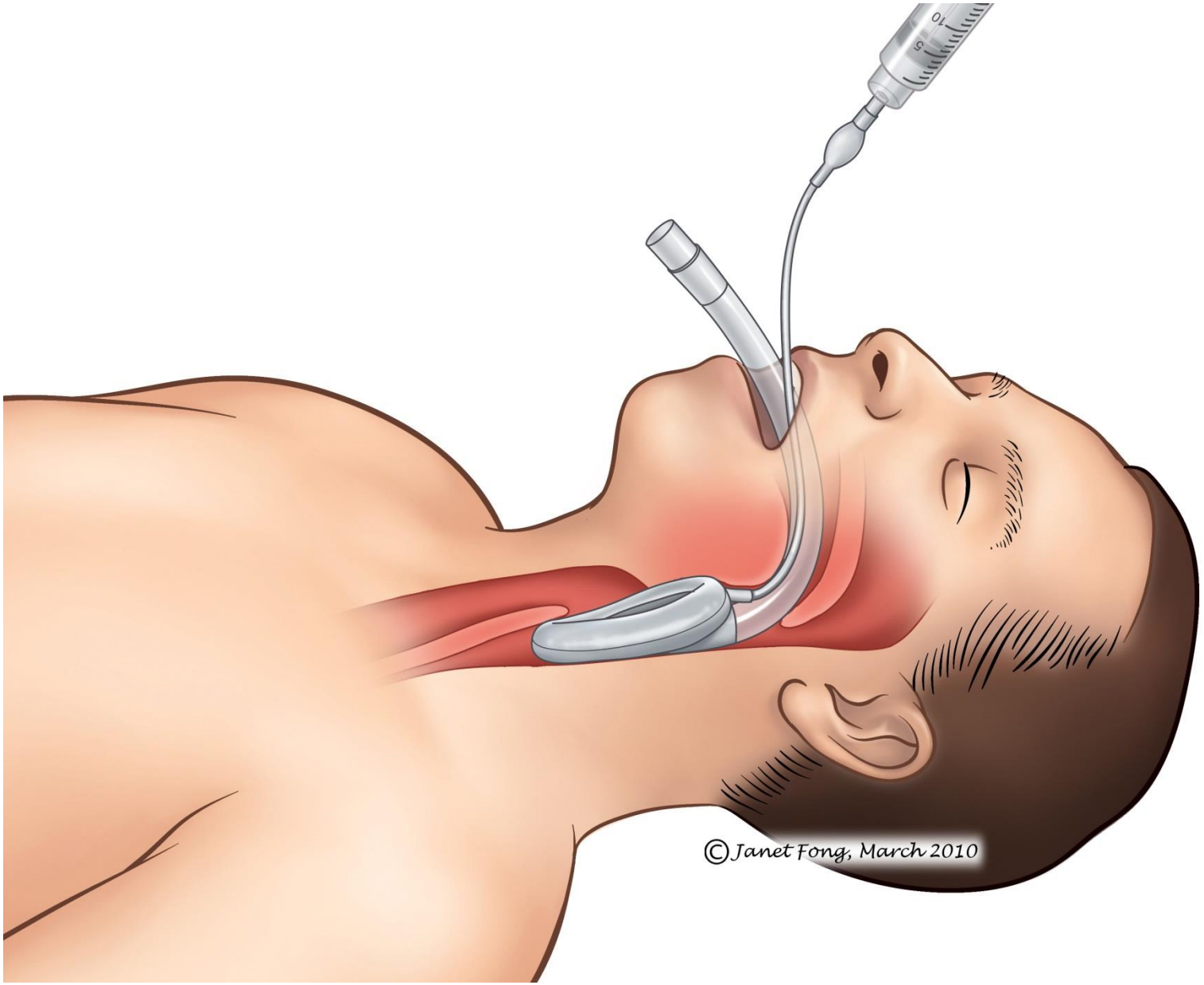
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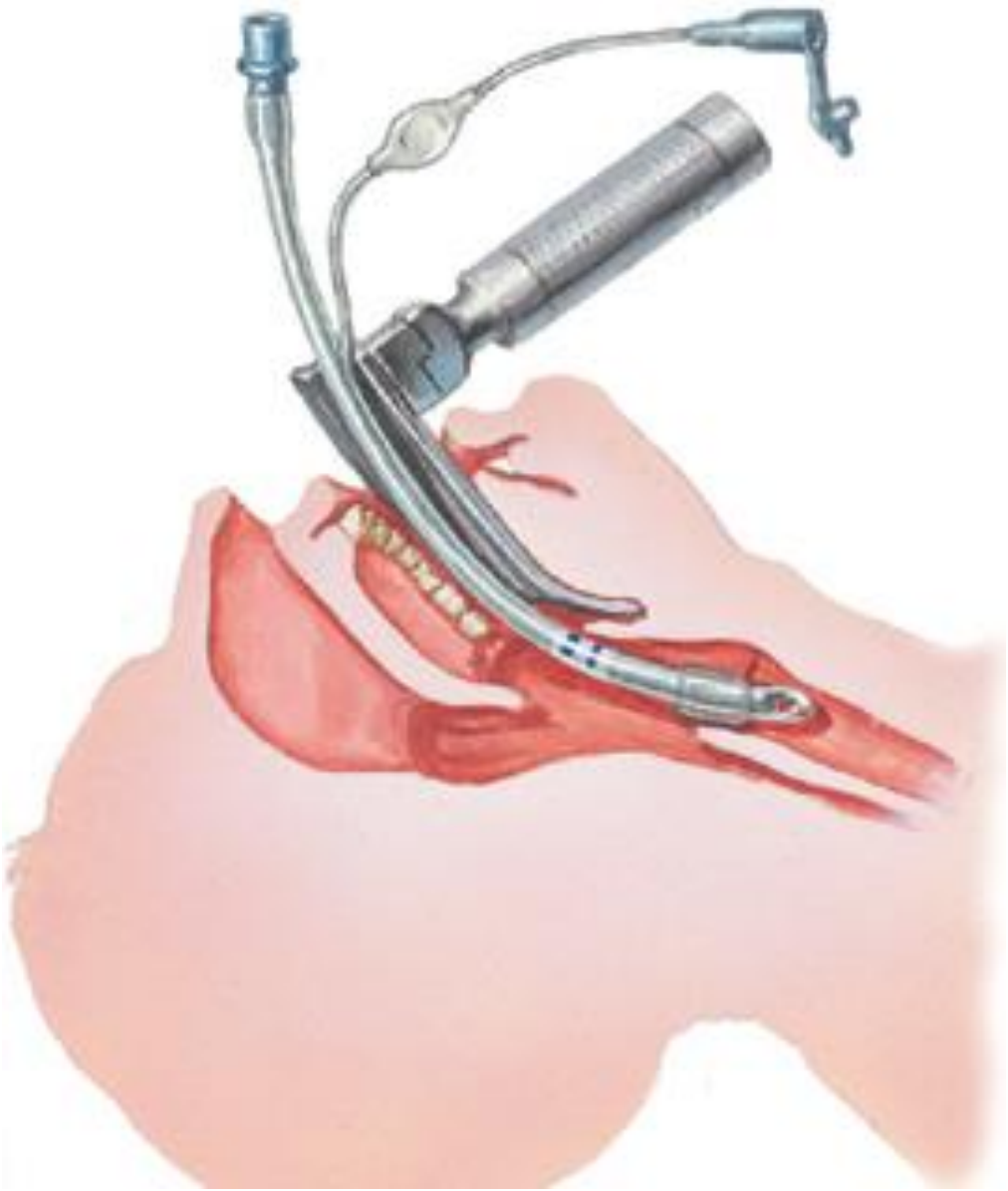
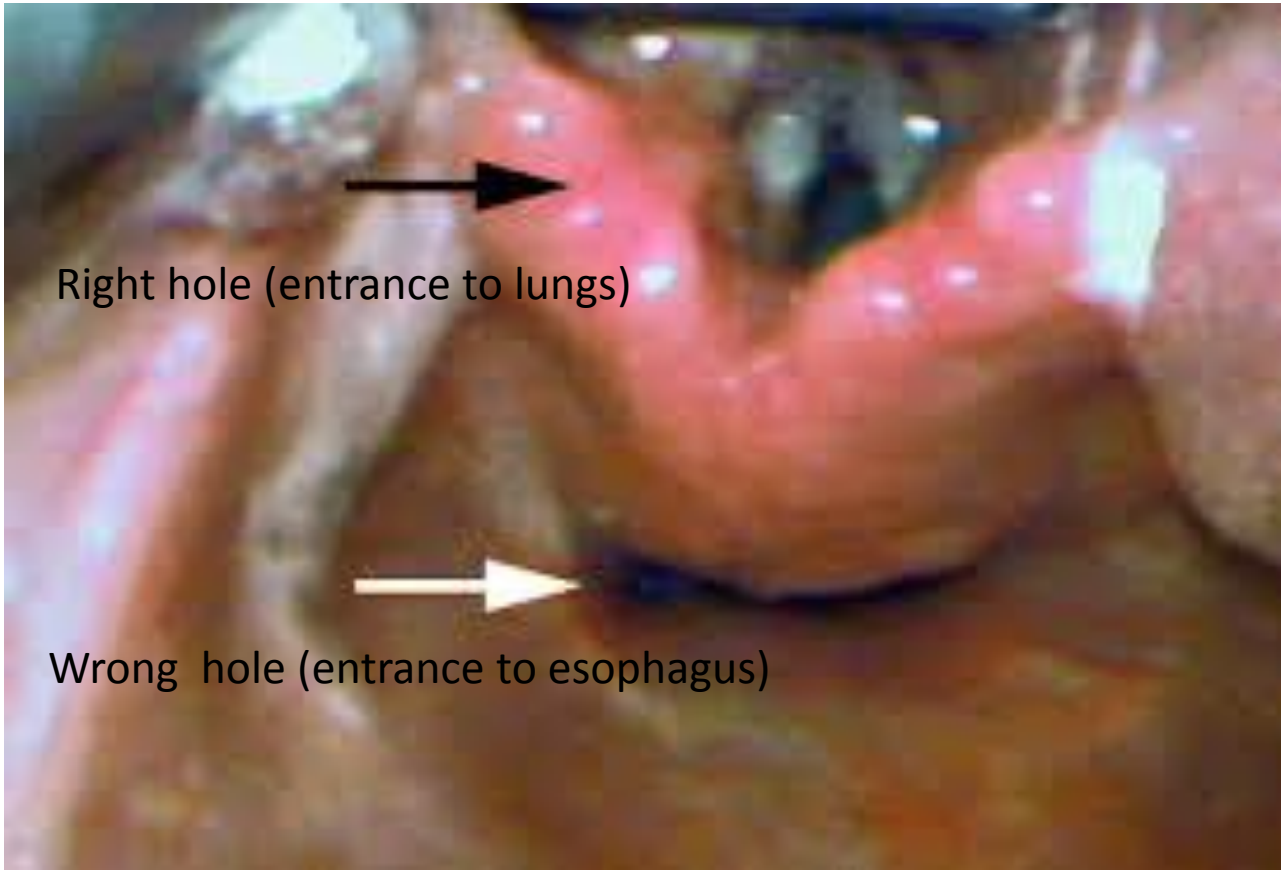


Tracheal Intubation

"An esophageal intubation is no sin, but there is great sin in not recognizing such a placement."



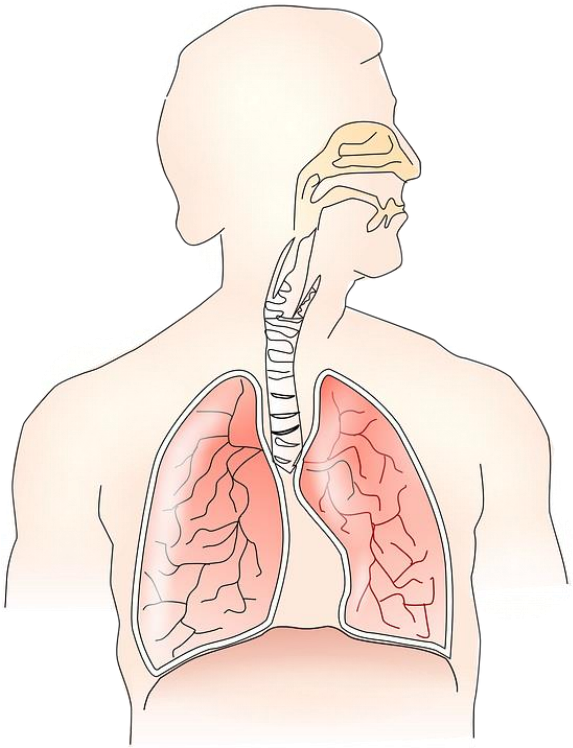

5'6"
686 lbs
(311kg)
BMI 110.7

Respiratory Monitoring Technologies

- Ancient methods
- Arterial blood gas analysis
- Capnography
- Pulse oximetry
- Spirometry (volume of air inhaled and exhaled)
- Thermistor-based methods
- Methods based on photoplethysmography
- Methods based on electrical impedance
- Methods based on piezoelectric film sensors
- Methods based on exhaled humidity

Ancient Methods of Respiratory Monitoring

- Watch breathing pattern *(chest, abdomen etc.)*
- Feel breath on hand placed over mouth
- See fog on mirror placed over the mouth
- Movement of little piece of cloth under nose



https://pixabay.com/en/anatomy-lungs-breathing-human-145696/
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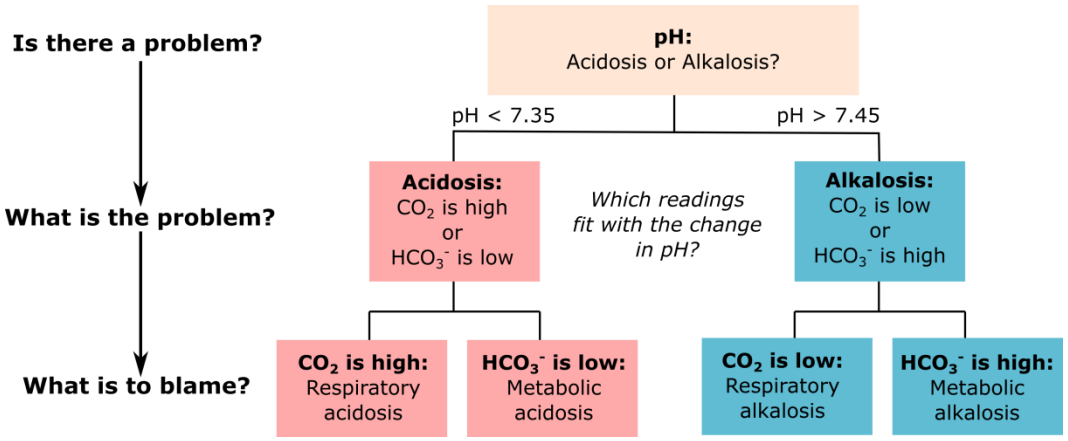
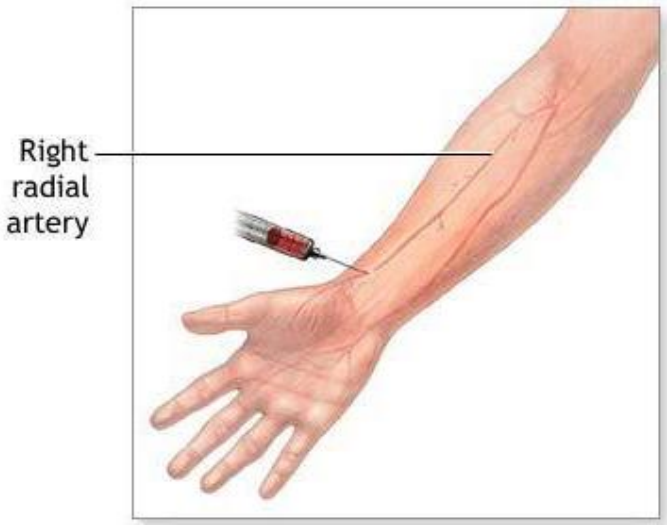
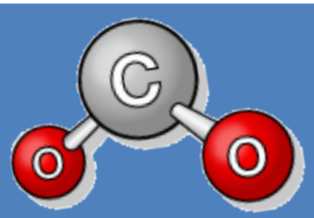
Arterial Blood Gas Analysis

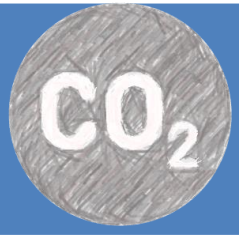


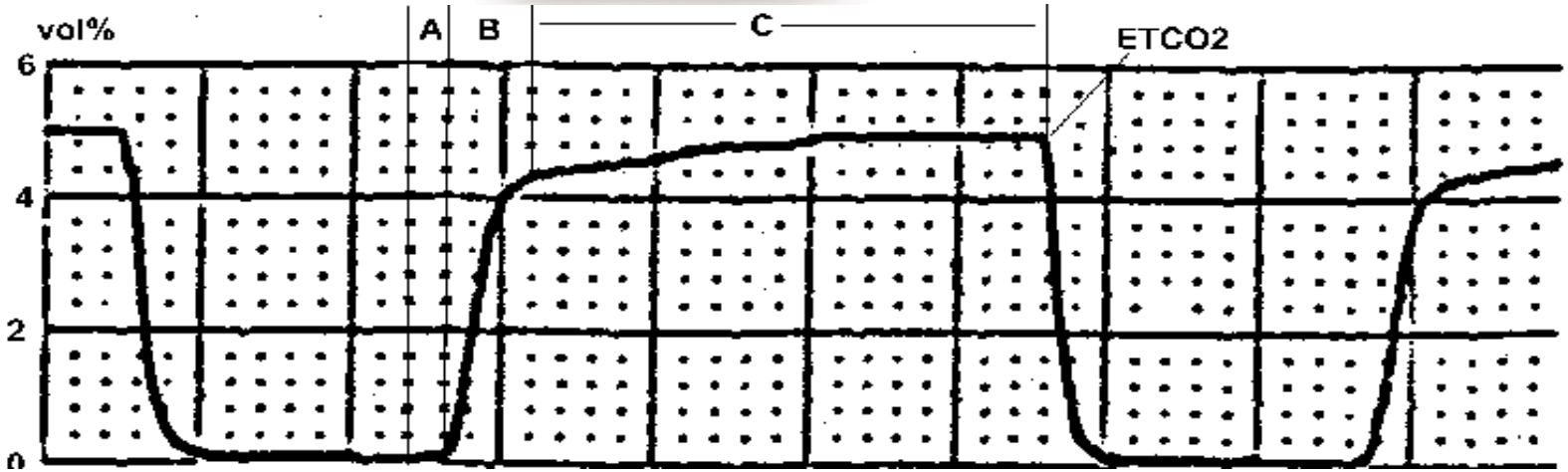


Analyte	Normal Value	Normal Range*
pH	7.40	7.35 to 7.45
$Paco_2$ (mmHg)	40	35 to 45
Hco_3- (mmol/L)	24	21 to 28
Pao_2 (mmHg)	100	80 to 110

Capnography

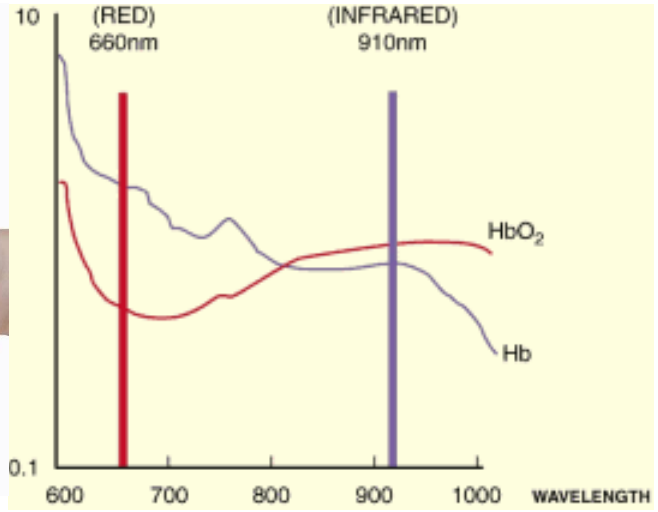






https://commons.wikimedia.org/wiki/File:Nasalprongs.JPG
http://www.medtronic.com/covidien/products/capnography
http://www.covidien.com/pace/clinical-education/channels/capnography
https://commons.wikimedia.org/wiki/File:Capnogram.png#/media/File:Capnogram.png

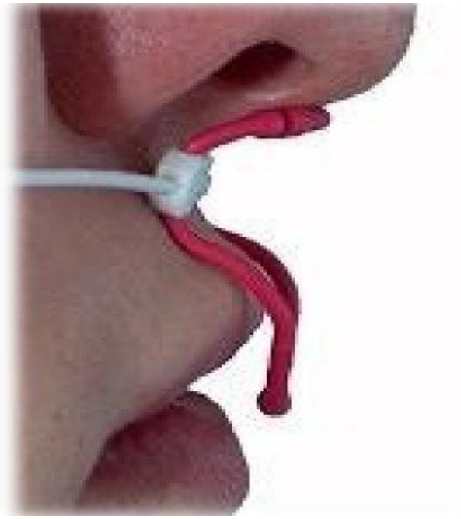
Pulse Oximetry

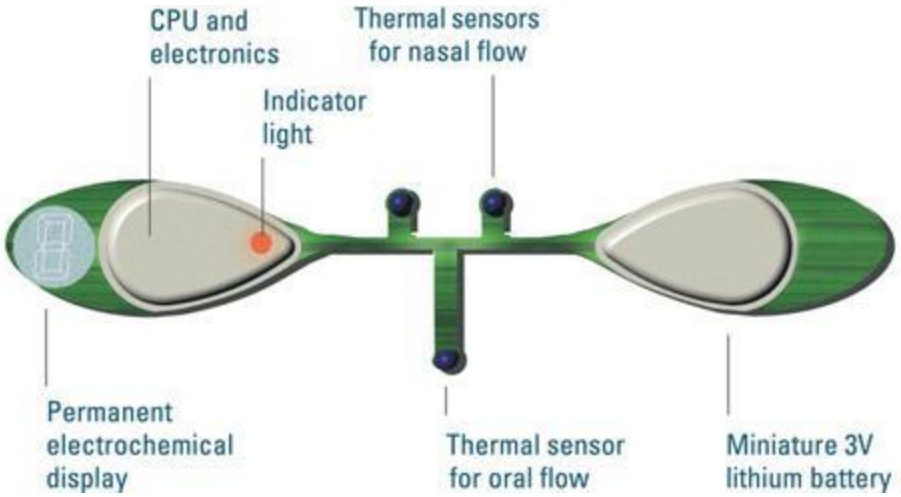


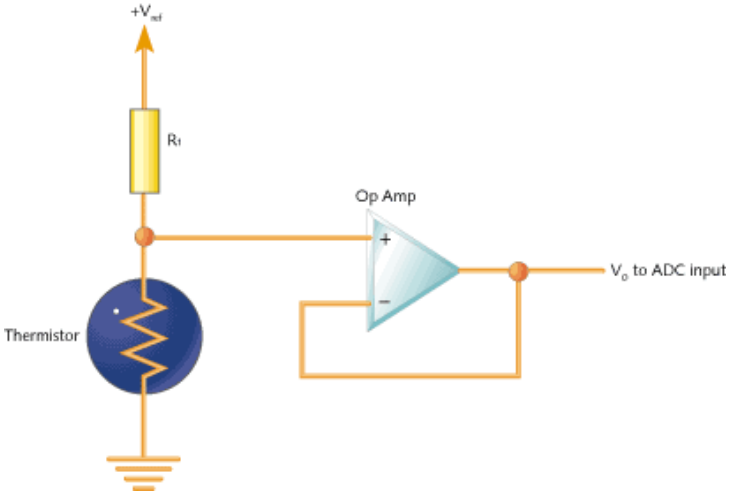
Pulse oximeter plethysmogram

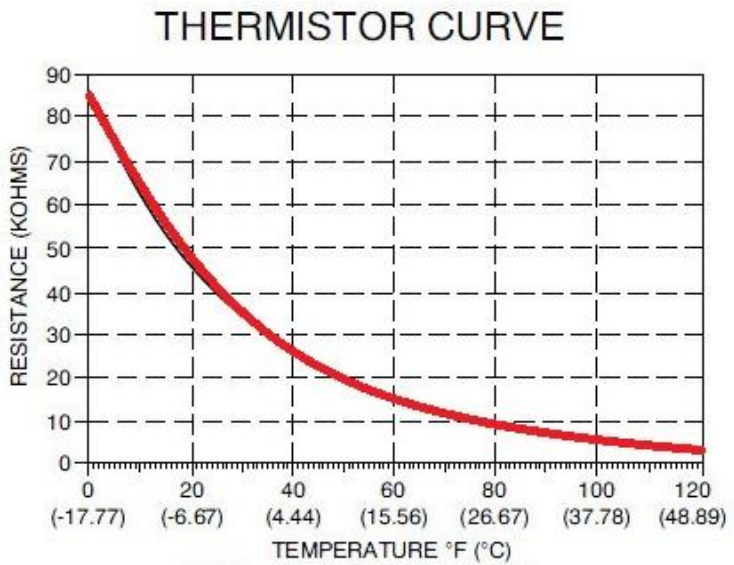
http://www.oximetry.org/pulseox/principles.htm
http://www.daviddarling.info/images/pulse_oximeter.jpg
http://www.apsf.org/newsletters/html/2011/spring/09_QA.htm

Thermistor-based Methods







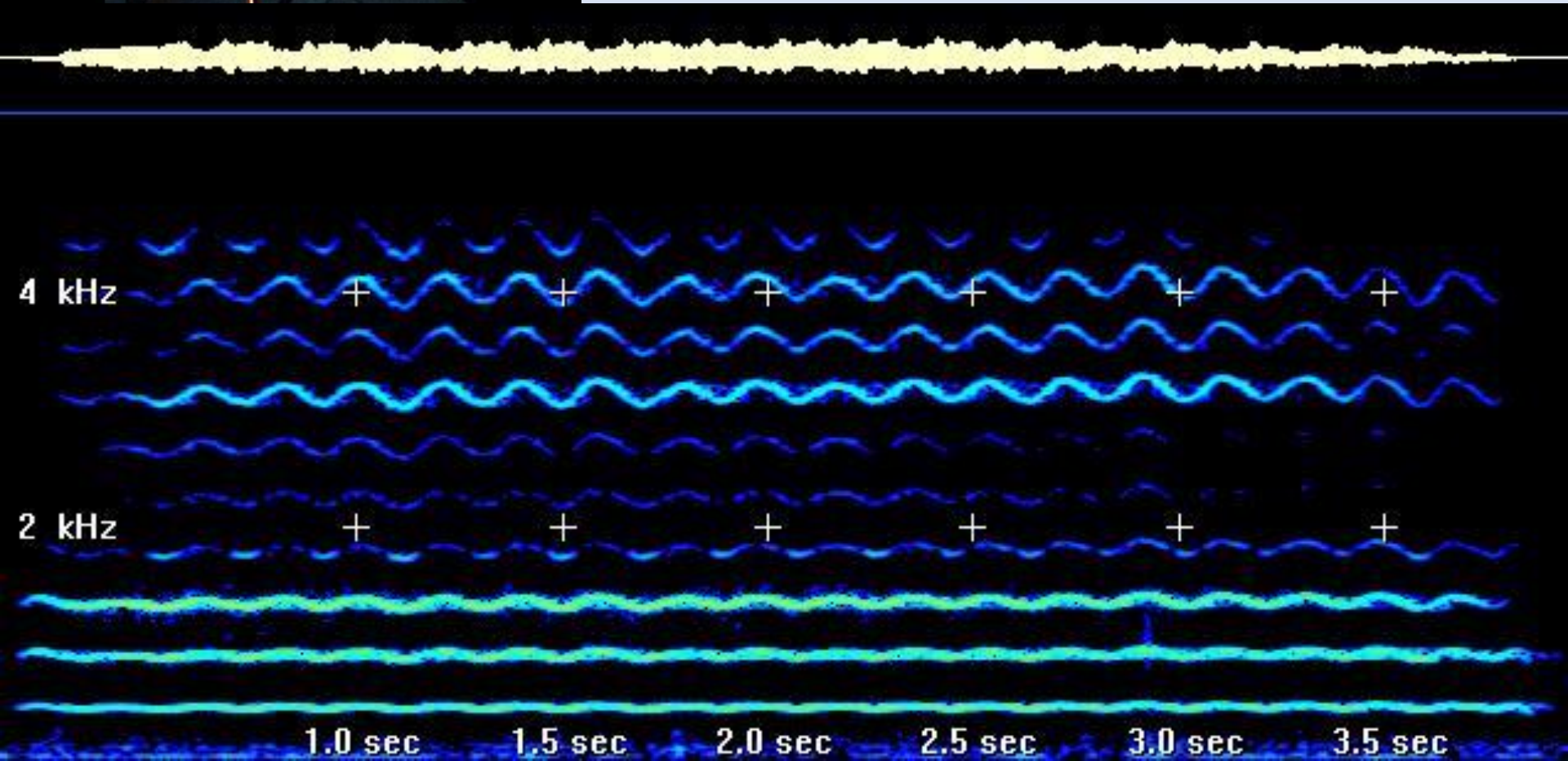


Color Spectrogram Analysis

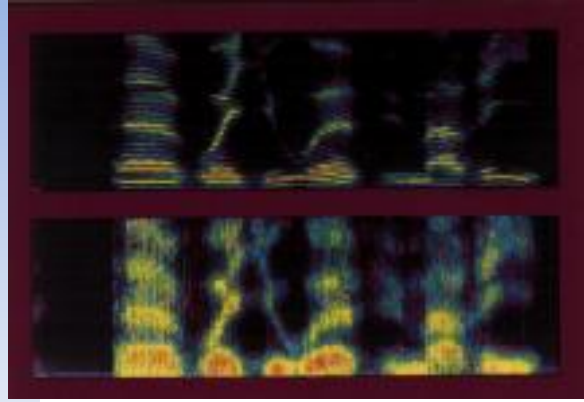
- Voice analysis
- Voiceprint identification
- Birdcall analysis
- Heart sound analysis
- **Respiratory sound analysis**

Color Spectrogram of the Singing Voice

http://www.visualizationsoftware.com/gram.html

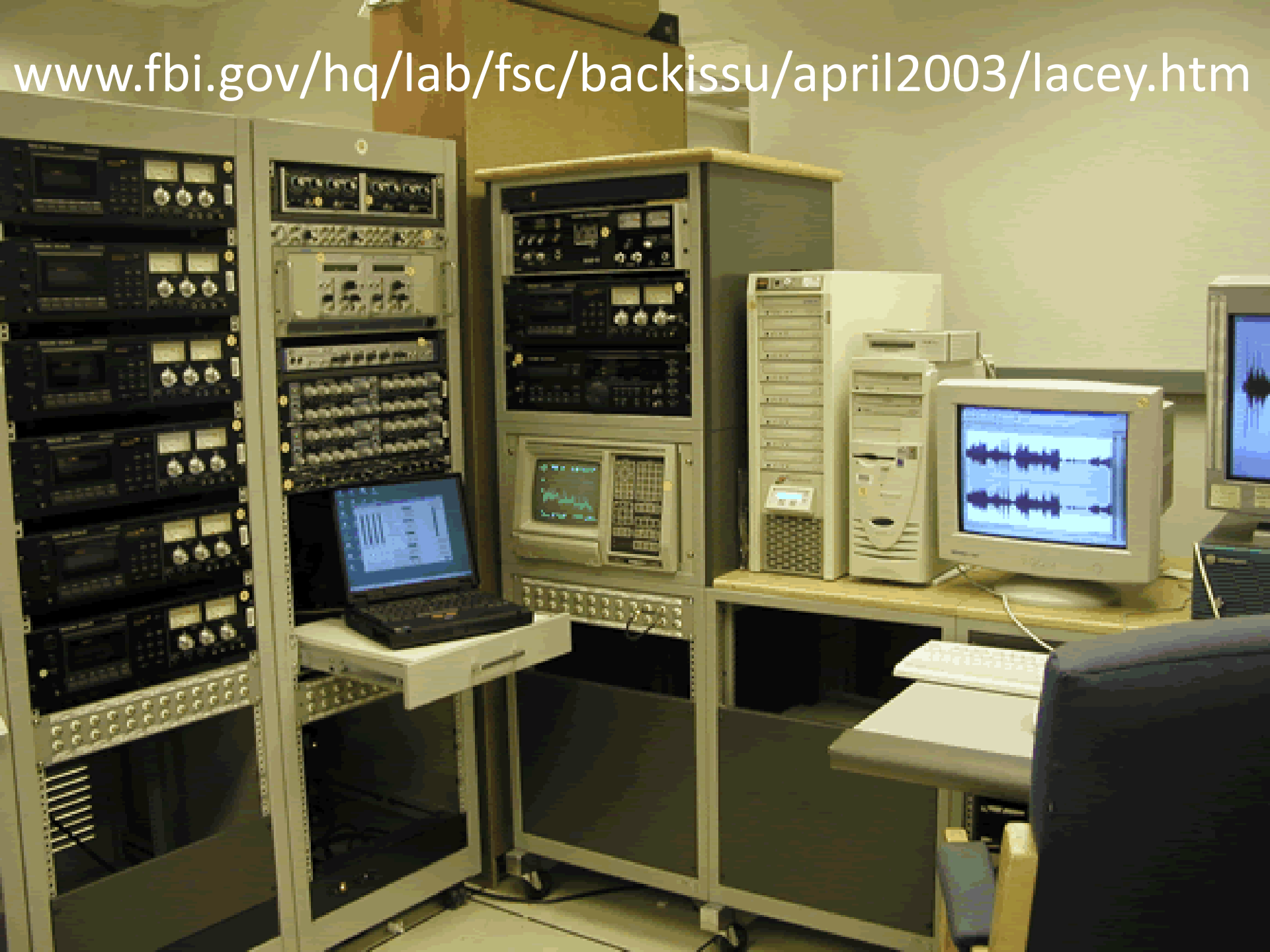


Application to Forensic Speaker Identification

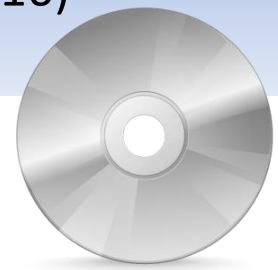


Forensic voice analysis is based on the principle that each voice is sufficiently characteristic to distinguish it from others. Factors in determining voice uniqueness lie in the size and configuration of the vocal cavities (throat, nasal, and oral cavities) and the shape, length and tension of the vocal cords. Another factor is the manner in which the articulator muscles are manipulated during speech.

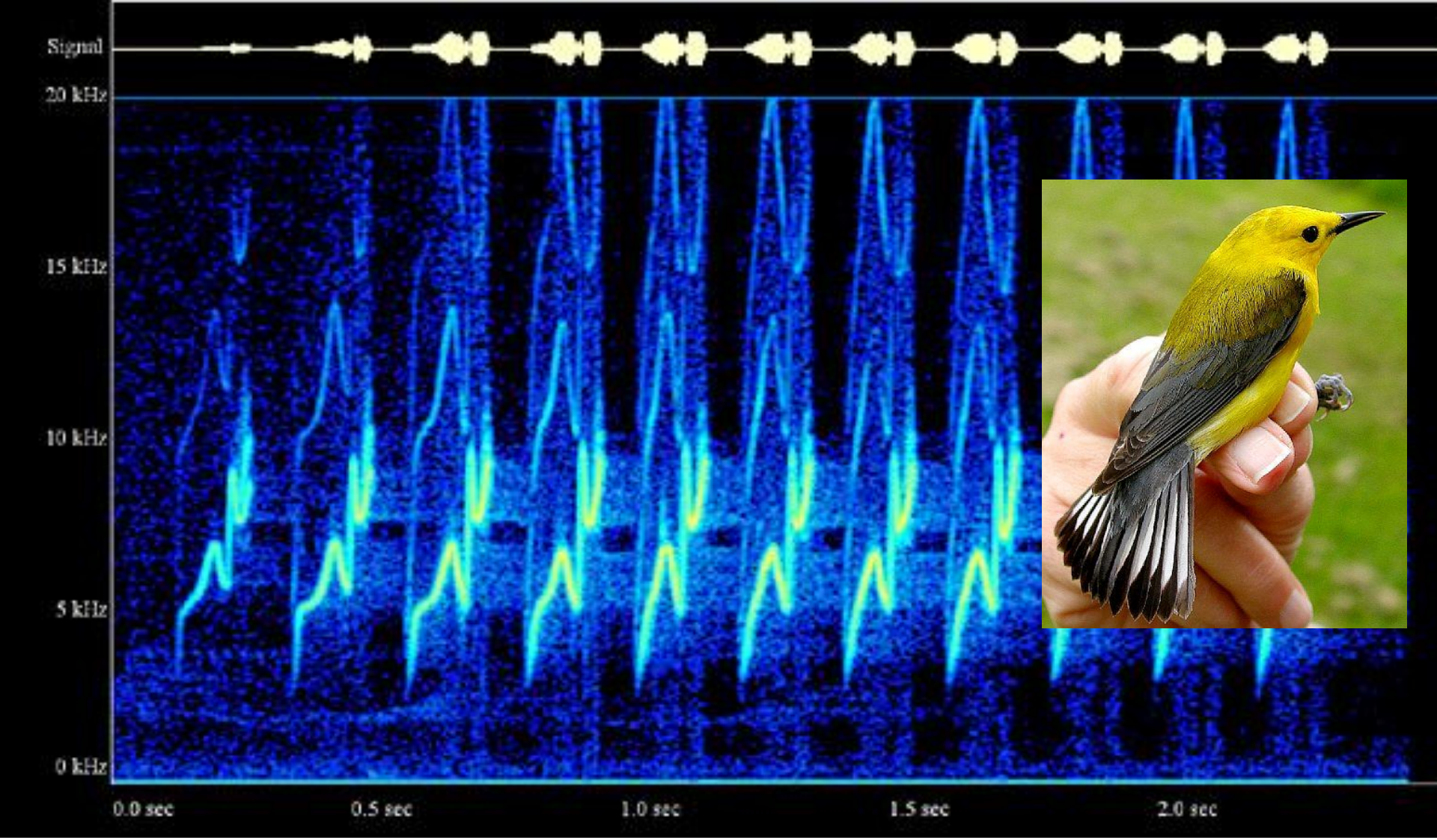
Modified from http://www.stutchmanforensic.com/


www.fbi.gov/hq/lab/fsc/backissu/april2003/lacey.htm

www.visualizationsoftware.com
Spectrogram (Version 16)
Freeware

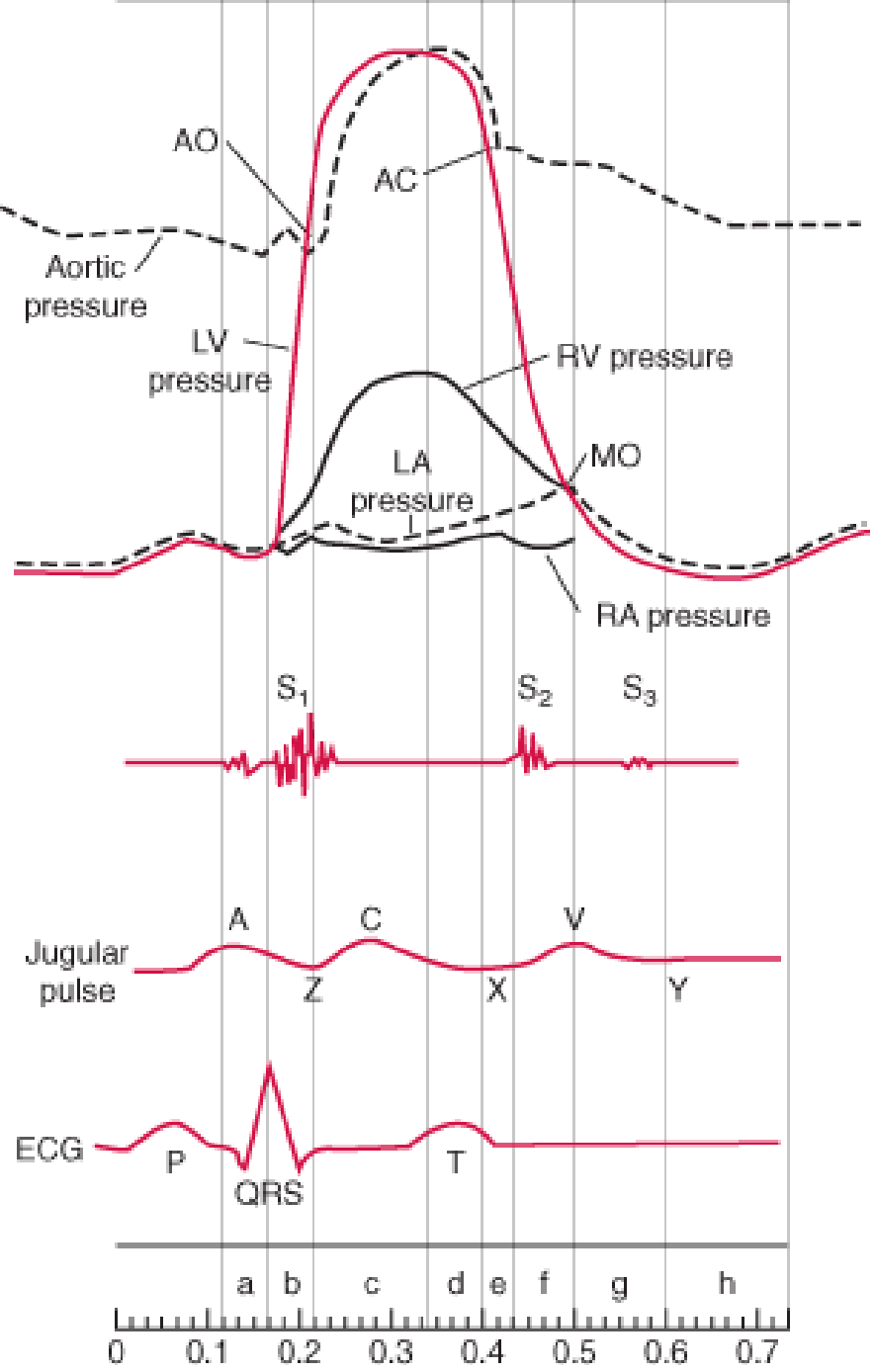


Setting up your own bioacoustics laboratory *(at almost no cost !)*

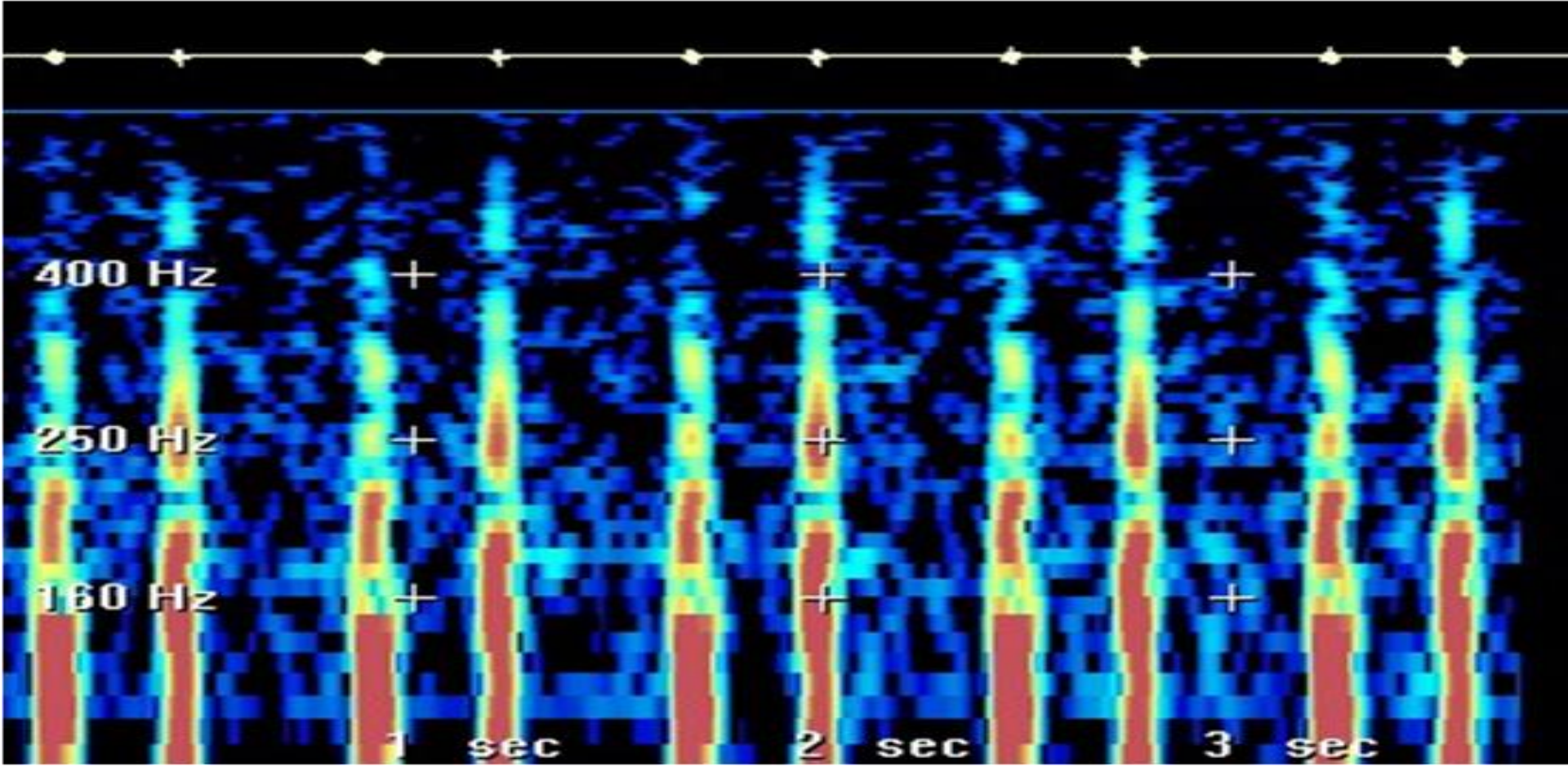


Color Spectrogram of the Song of the Prothonotary Warbler

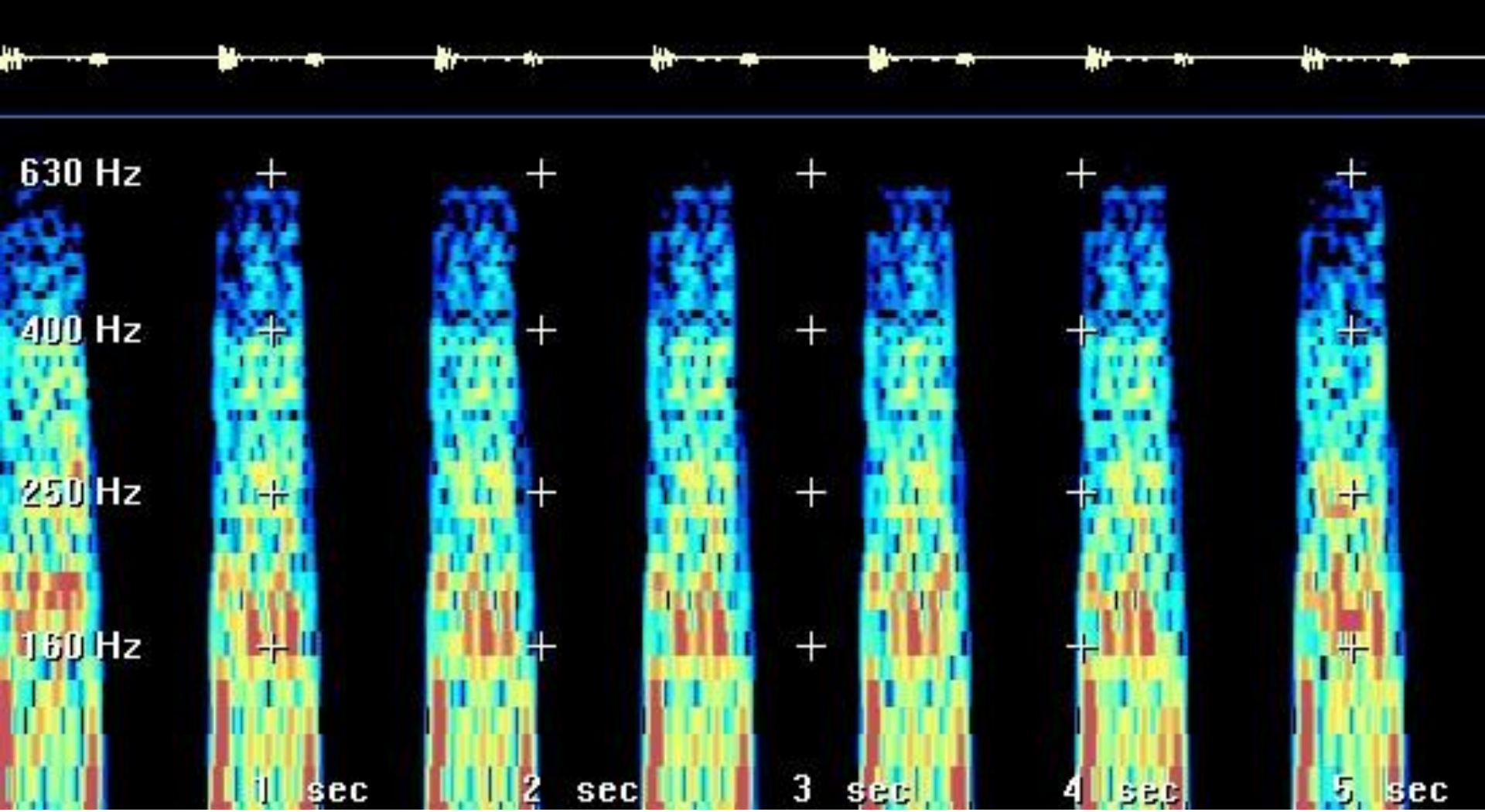
http://www.visualizationsoftware.com/gram.html



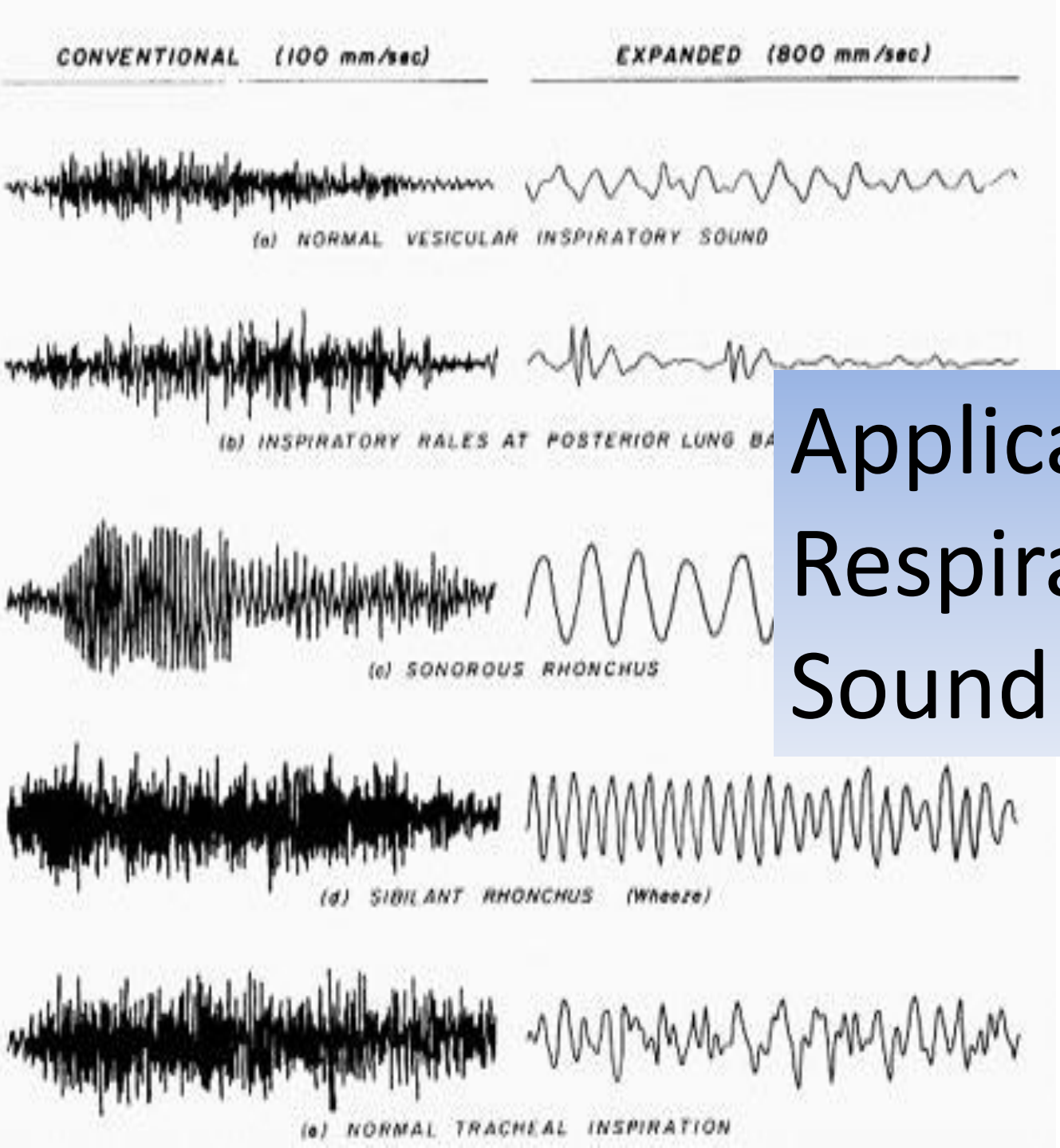
Application to Heart Sound Analysis



Color spectrogram analysis of a normal phonocardiogram, showing the first and second heart sounds. The signal intensity is colored as follows: red > yellow > green > blue > black. Note that the vertical axis is logarithmic while the horizontal axis is linear. The time-domain phonocardiogram is shown at the top.



Spectrogram obtained from an individual known to have a pansystolic murmur. Note that the first and second heart sounds are completely obscured by the murmur.

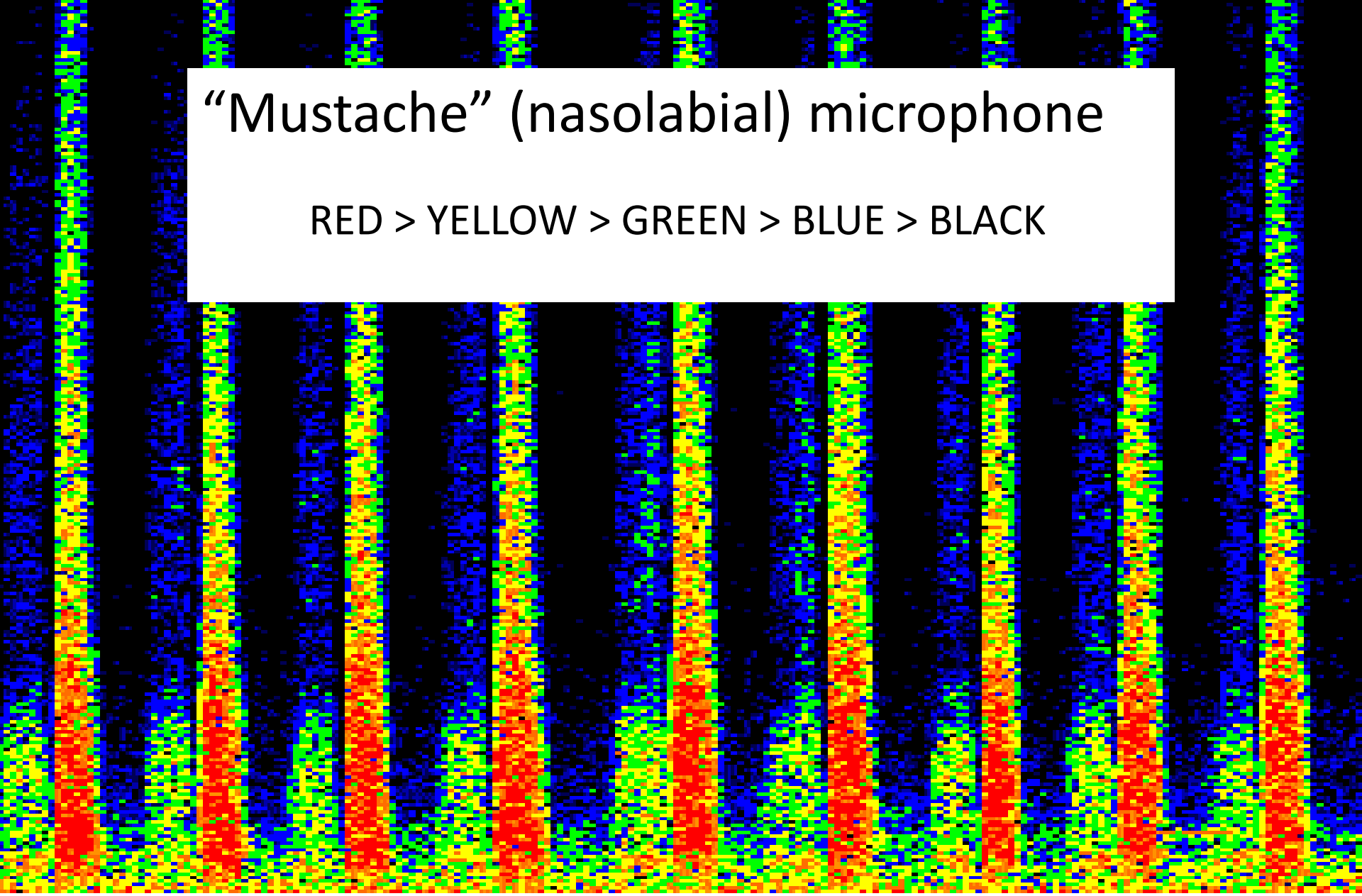


Application to Respiratory Sound Analysis

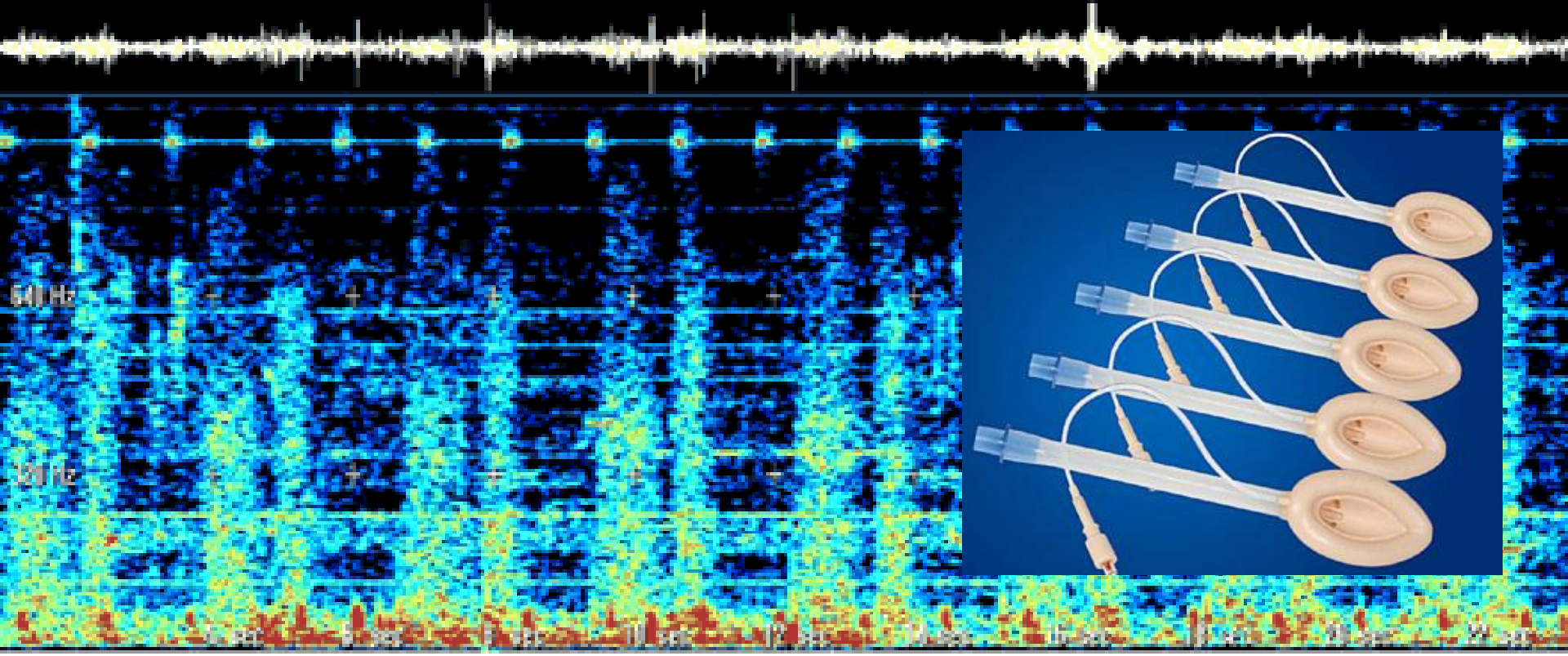
Respiratory Monitoring Using Color Spectrographic Analysis

Respiratory Sound Analysis: Possible Recording Sites

- Anterior or posterior chest wall
  (use two microphones to detect one-lung ventilation)
- LMA / ETT cuff inflation port
  (requires special leak-free microphones)
- "Mustache" (nasolabial) microphone
- Microphone in oxygen mask
- Microphone in ear canal

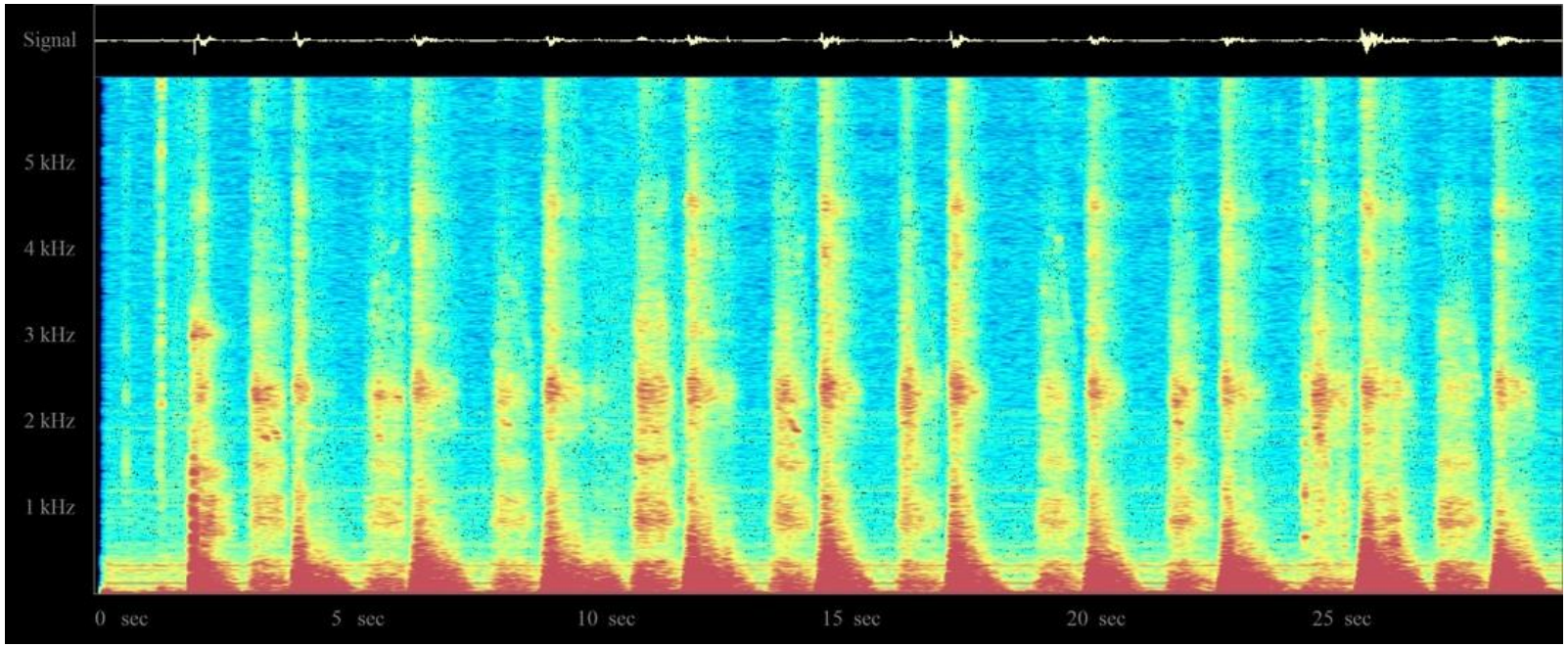


Respiratory spectrogram obtained during sleep.

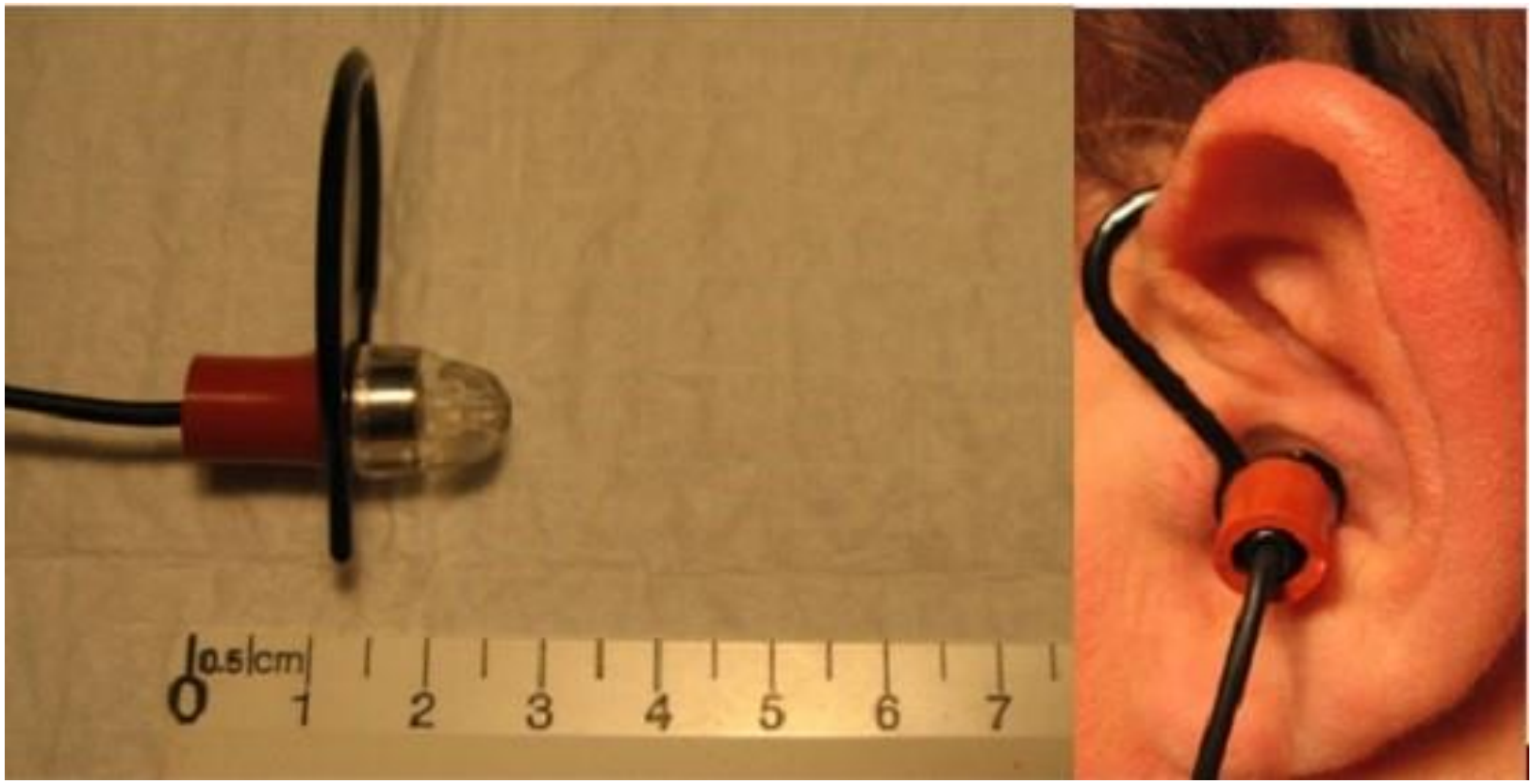


Sample color spectrogram of eight respiratory cycles of breath sounds (inspiration plus expiration) obtained from the LMA in a spontaneously breathing patient under general anesthesia. Note that the inspiratory phase of the signal lasts somewhat longer than the expiratory phase and has slightly less high frequency components. Note also that there is little or no signal energy beyond 900 Hz. The cardiac monitor "beep" associated with each heart beat (918 Hz) is also visible near the top. At the very top is displayed the raw time-domain signal. The audio portion of this recording may be downloaded and played on suitably equipped computers by visiting http://lmamonitor.homestead.com.
[Color scale: RED > YELLOW > GREEN > BLUE > BLACK]
From http://www.cja-jca.org/cgi/content-nw/full/50/suppl_1/A113/F

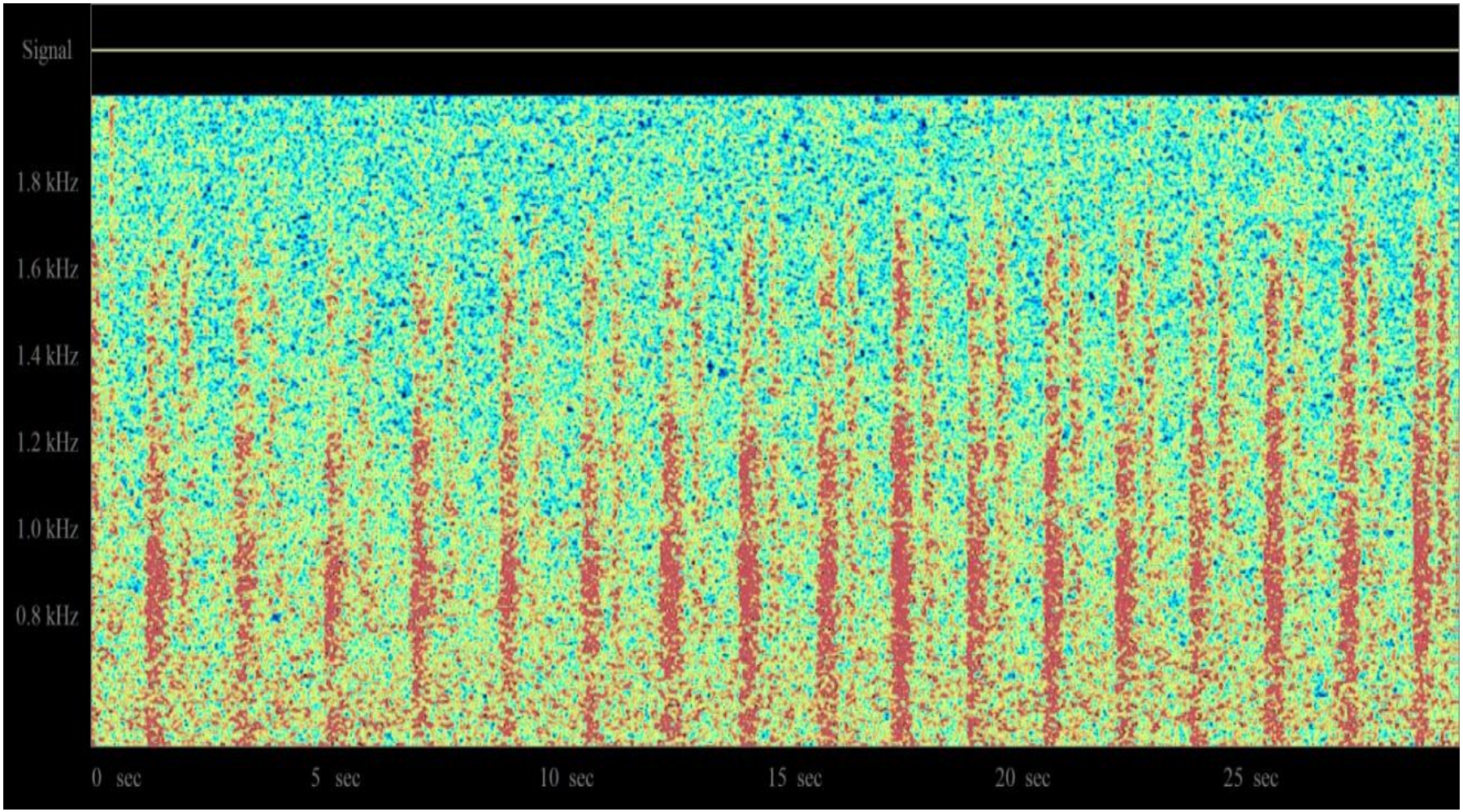
RED > YELLOW > GREEN > BLUE > BLACK



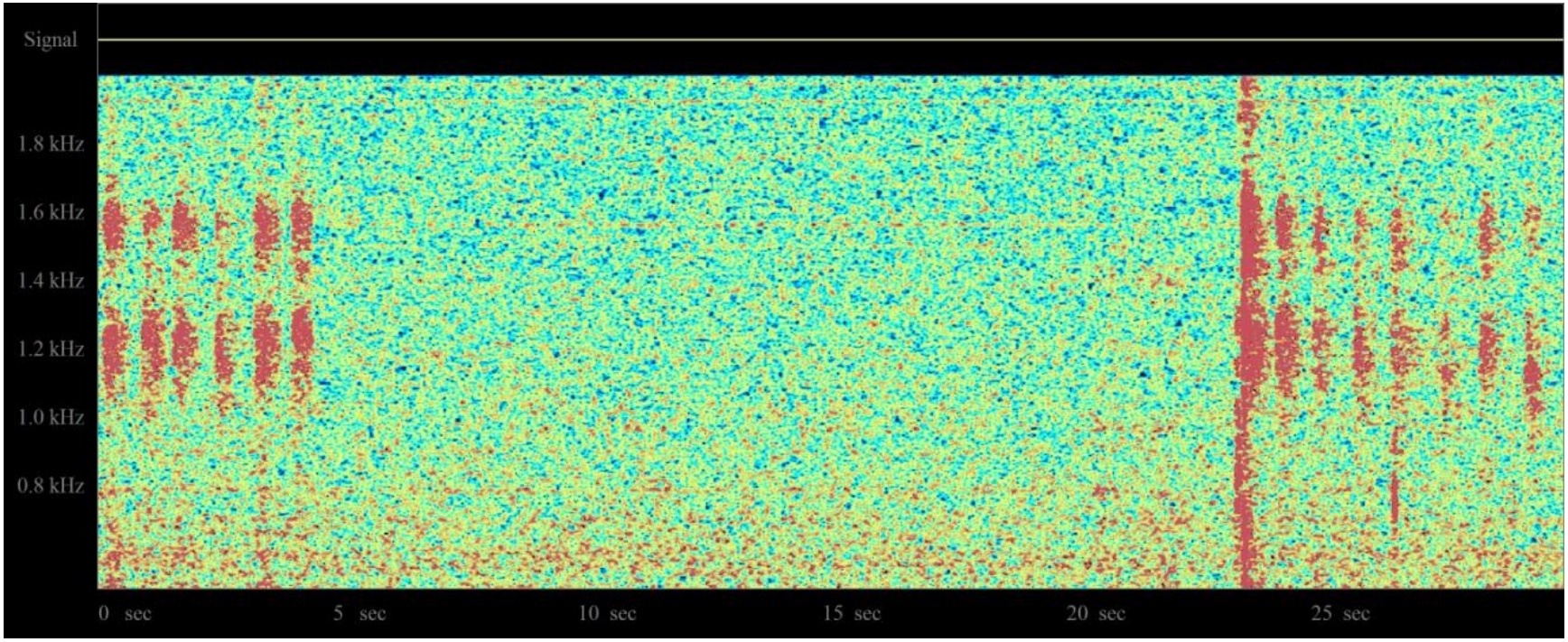
COLOR SPECTROGRAPHIC RESPIRATORY MONITORING FROM THE EXTERNAL EAR CANAL



COLOR SPECTROGRAPHIC RESPIRATORY MONITORING FROM THE EXTERNAL EAR CANAL



COLOR SPECTROGRAPHIC RESPIRATORY MONITORING FROM THE EXTERNAL EAR CANAL



Breath holding

The End

Thank You for Listening