IFOS 1-5 June, 2009

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

The normal development of voice in childhood

Instruction course

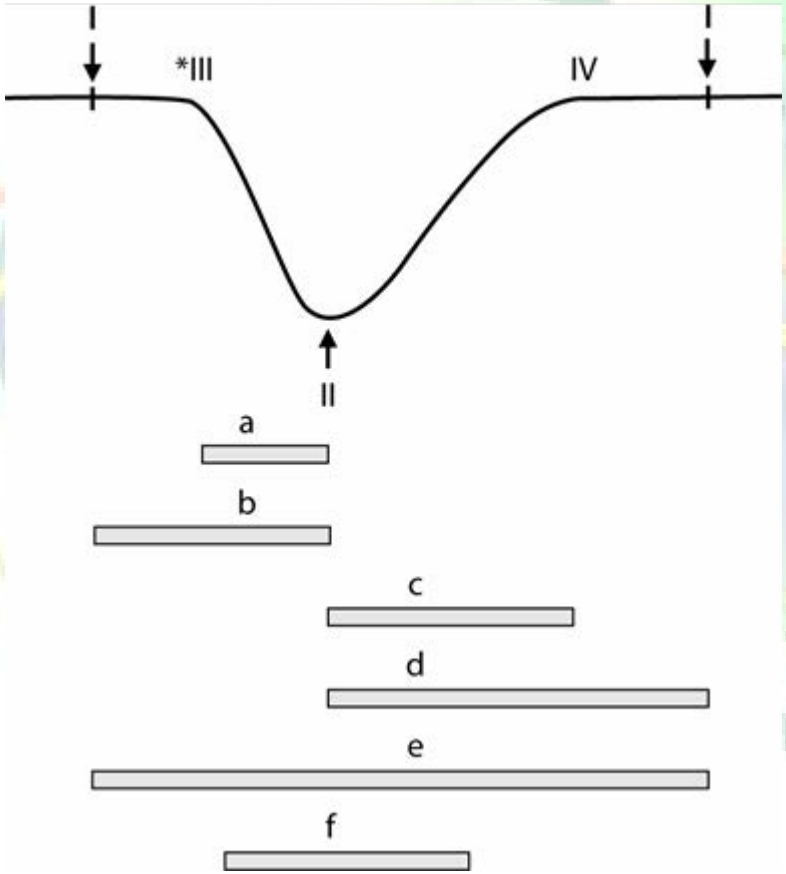
M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

- Mette Pedersen

- FRSM Dr.med.Sci. et h.c. Ear-Nose-Throat specialist
- Delegate from the Danish Ministry of science in the European Union.
- New book: http://www.springer.com/978-3-540-69358-1

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

The electroglottical curve at the laryngeal level



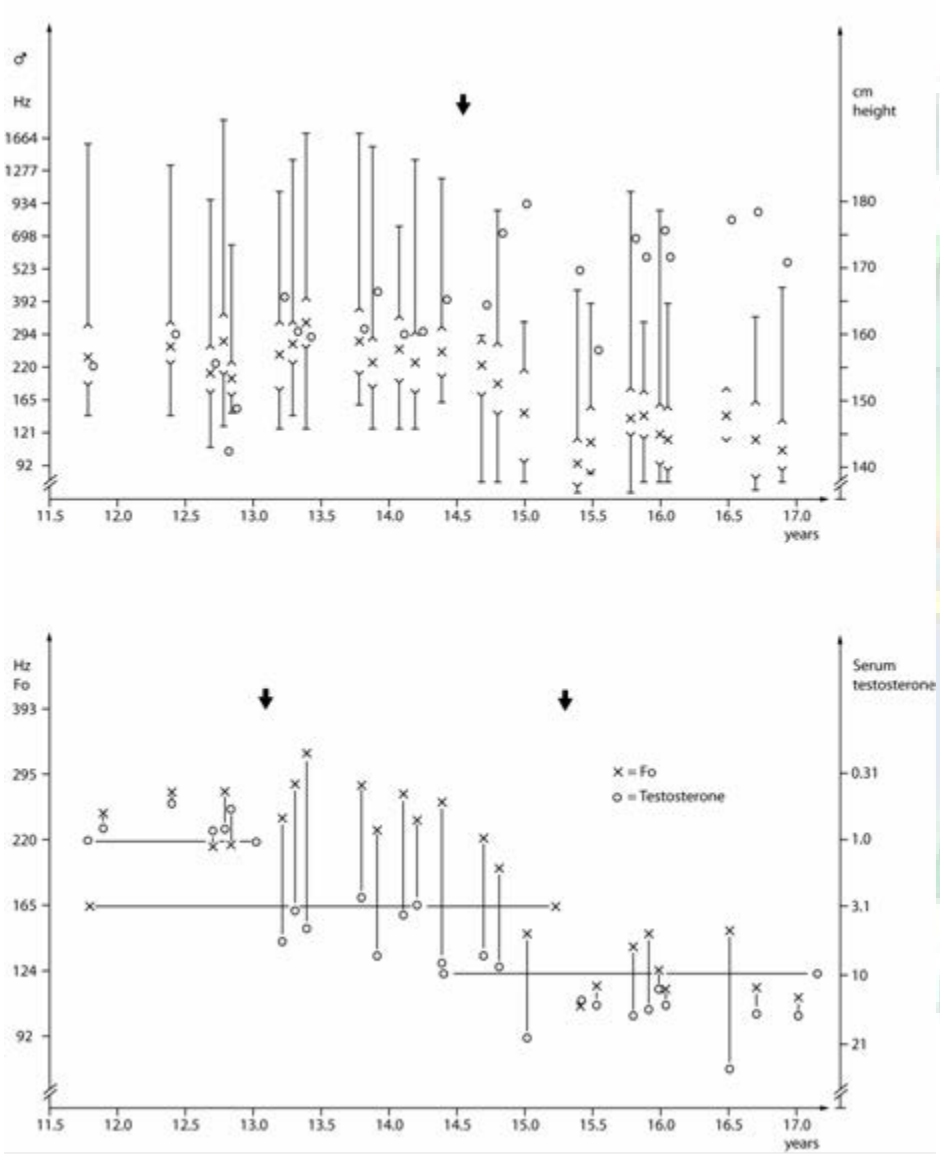
- **I:** maximum opening of the glottis
- **II:**maximum closing of the glottis (stroboscopically determined and transferred from the electroglottography curve).
- **III** and **IV** represent the change in resistance during the transition between these two states

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

Measurements with the Danish standard text, phonetically balanced:

"The Northern wind and the Sun"

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

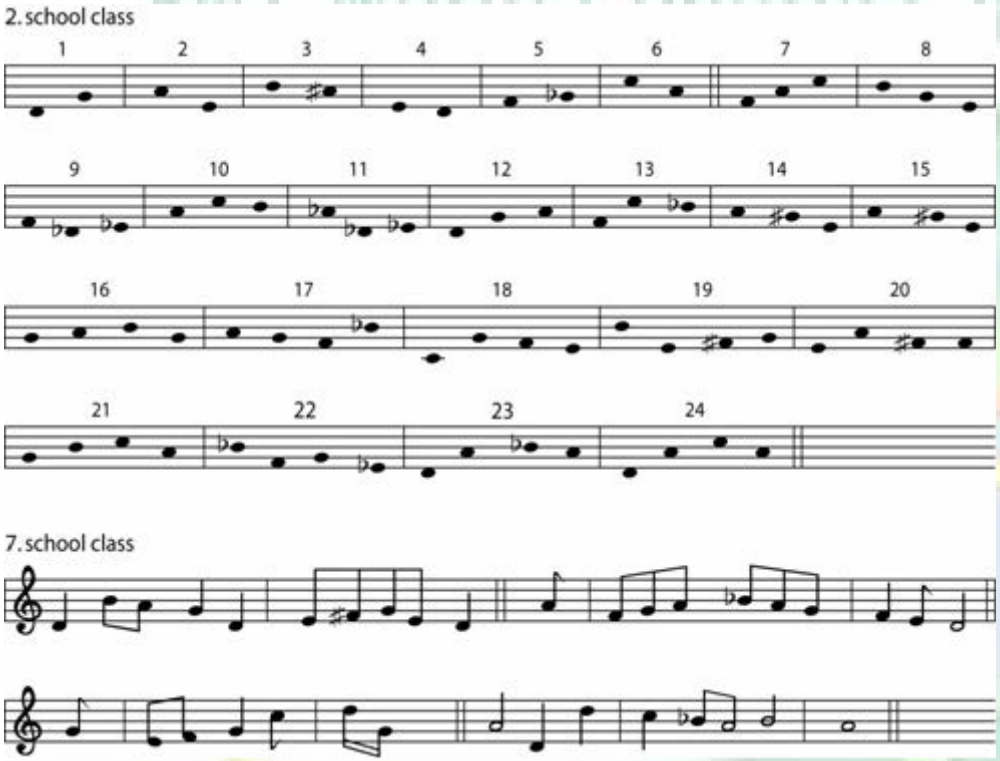


Range of fundamental frequency 15% pr centiles from 1-784 Hz

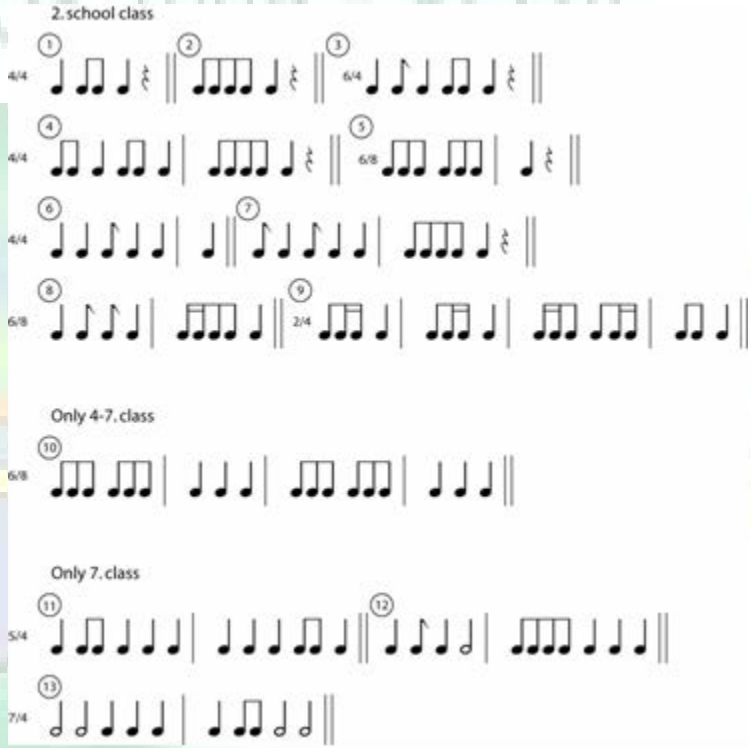
- ***Above**: Fundamental frequency of the speaking voice, tonal range of the speaking voice and tonal range of the singing voice for boys compared to body height (ordinate) and age (abcissa).*

- ***Below**: Fundamental frequency of the speaking voice [Hz] compared to serum testosterone level [nmol/l]. The abcissa shows the age in years. The arrows indicate the change of voice (above: End of the change; below: Beginning and end of the change).*

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org



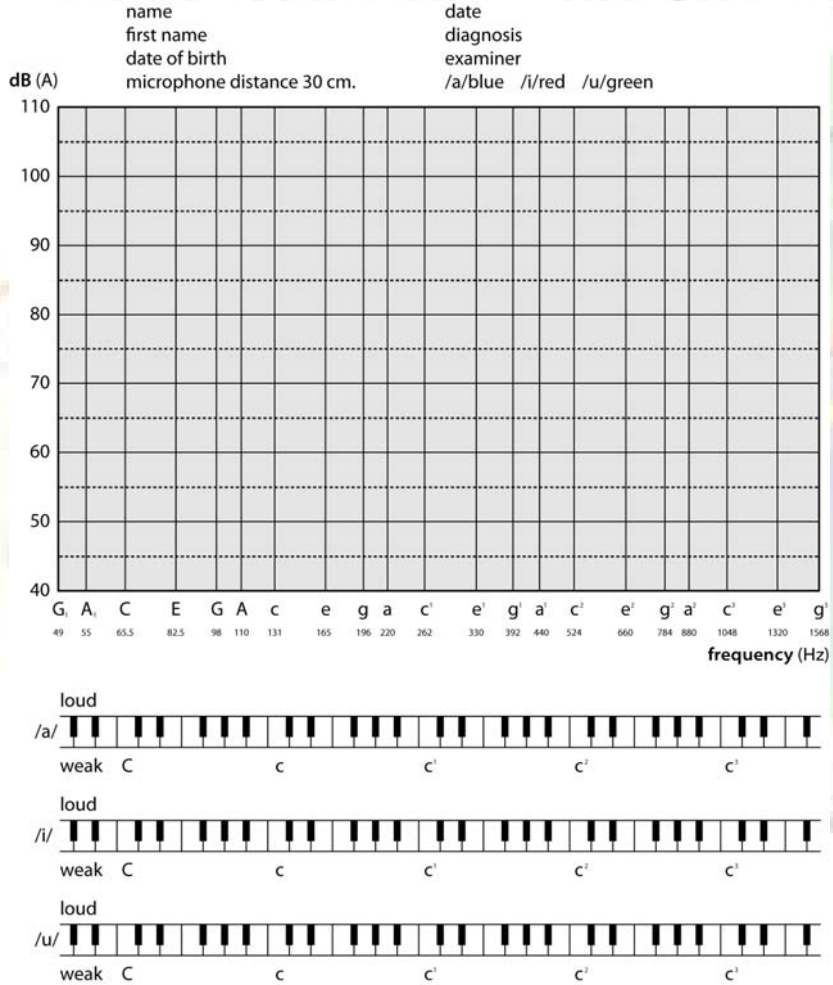
Wöldike's Musicality test- Reproducing a note.



Wöldike's rhythm test.

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

The phonetogram structure



Form for phonetogram measurement according to the 1981 UEP standardisation proposal.

Reproduction of the semitones is given with 30 cm distance and measured with an intensity meter from Bruel and Kjær, Type 2208

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

- Planimetry was made on paper in the study of the normal development.To calculate the area of voice intensity versus fundamental frequency, one cm2 was comparable to 32 dB(A) x semitones.

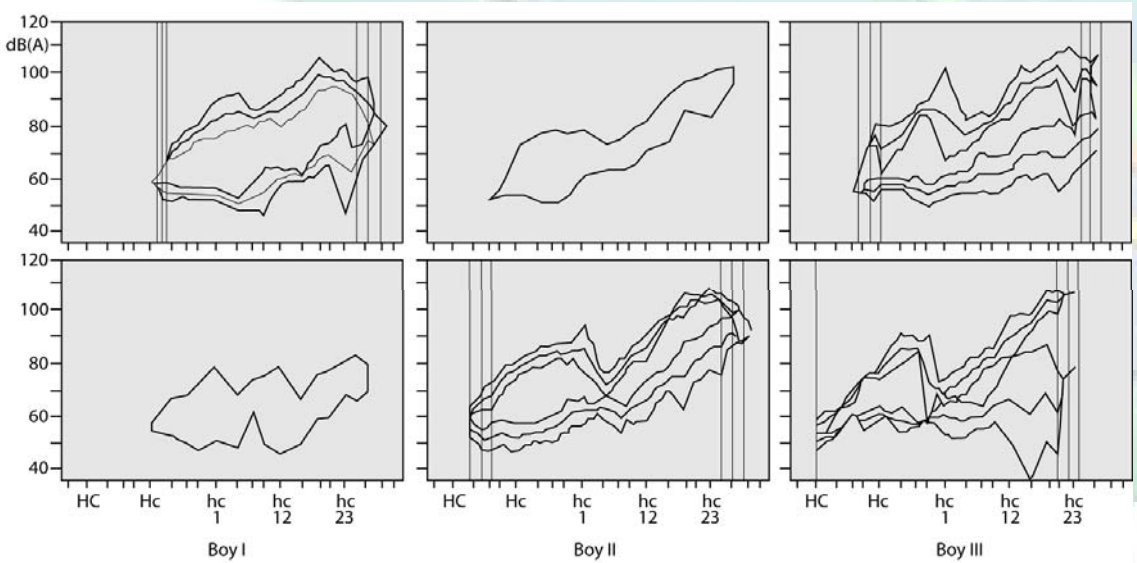
- Later on, we constructed a **phonetograph hardware** where the semitones were given automatically, whereafter a filter secured the voice source fundamental frequency.

- The maximal and minimal intensity was measured averaging 10 equal sinus curves respectively.

- Later on, we developed a software program known as PG 100. PG 200 is an averaging program with standard deviations of the measured tones**.**

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

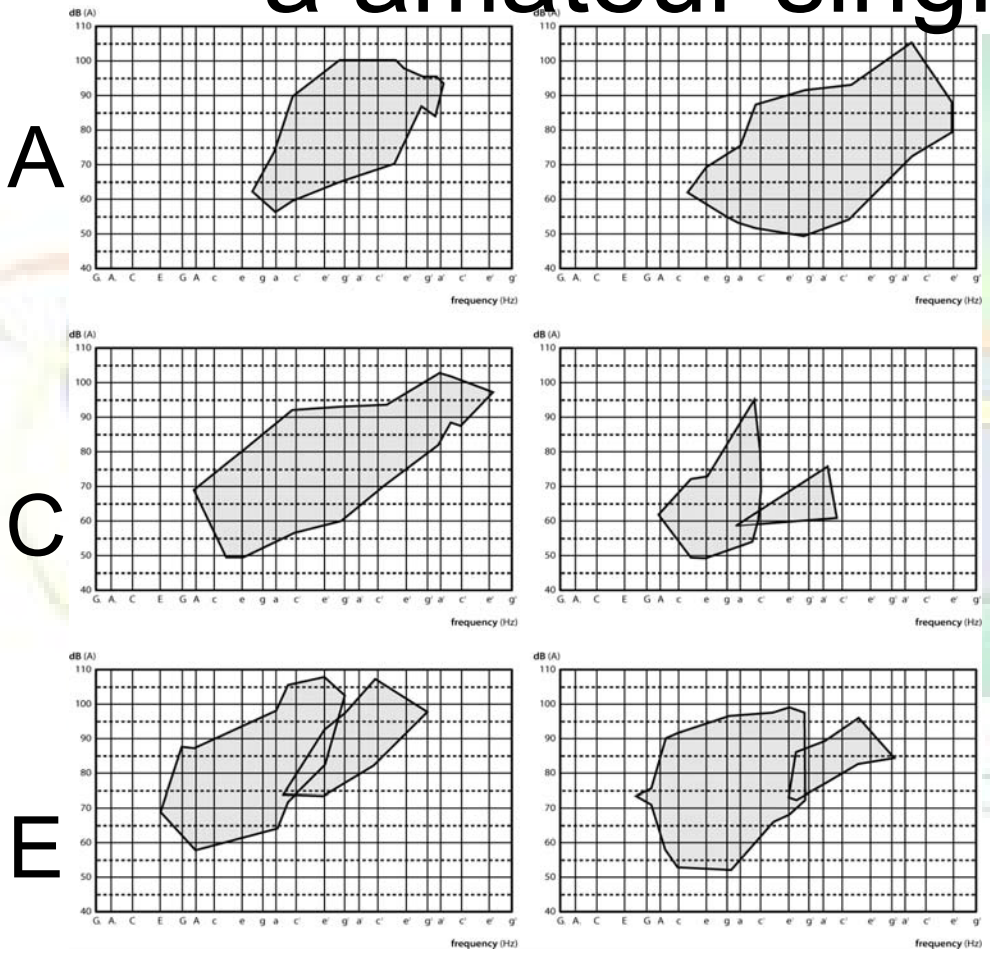
Average of phonetograms, made with PG200



- Average phonetograms and standard deviations for the three choirboys (I – III) involved in the prospective longitudinal study.
- The phonetograms before and after the change of voice were compared.
- For test person I and II, only one phonetogram was made in mutation and before mutation respectivetly.
- For test person III, three phonetograms were measured before and three during the change of voice.

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

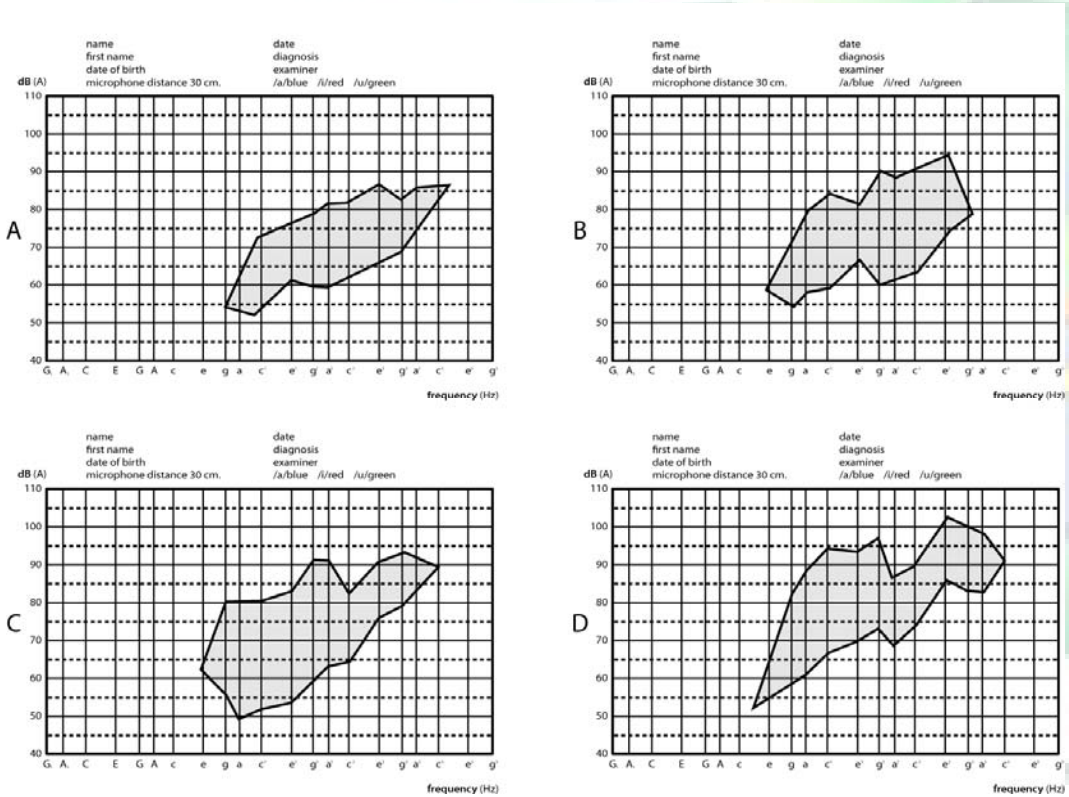
48 boys & 47 girls from 3-11 degree in a amateur singing school



- This was made using the model from the Union of European Phoniatricians 1981.
- Average phonetograms for boys and young men, depending on voice type. (The voice type was determined by the singing teacher.)
- **A:** Beginner
- **B:** Soprano
- **C:** Alto
- **D:** Voice in puberty
- **E:** Tenor
- **F:** Bass

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

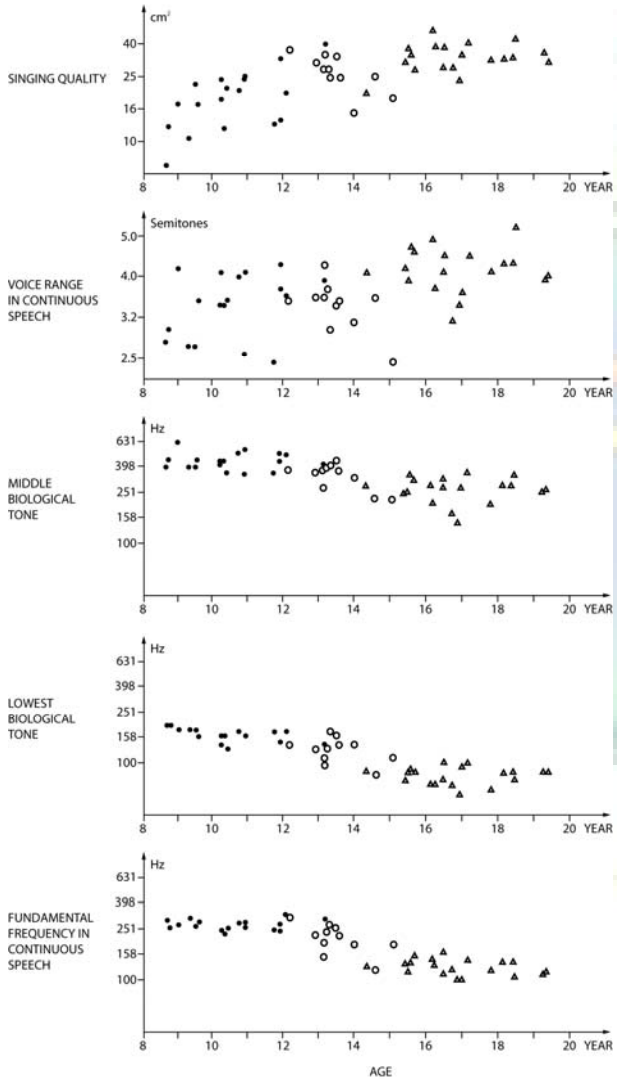
48 boys & 47 girls from 3-11 degree in a amateur singing school



- Phonetograms for girls of different ages.
- **A** (8.9 yrs.) – Beginner in the choir.
- **B** (11.7 yrs.) - Typical child's voice with change of register (330 - 392 Hz).
- **C** (13.8 yrs.) – Well-trained voice without register changes with limited dynamic breadth.
- **D** (14.8 yrs.) – Pubertal voice with register changes.

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

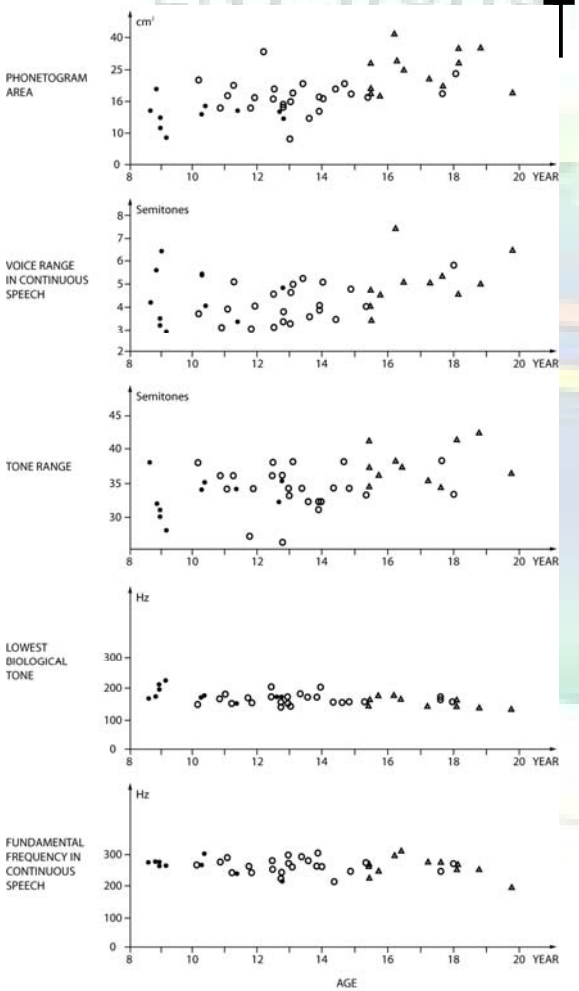
Development of fundamental frequency in boys



- Graphical representation of:
  - the phonetogram areas
  - the tonal range of the speaking voice
  - the deepest and the mean note in the phonetogram
  - the fundamental frequency of the speaking voice for boys as a function of age (abcissa):
    - (•) 8,7 -12,9 years,
    - (O) 13 - 15,9 years,
    - (Δ) 16 - 19,5 years.

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

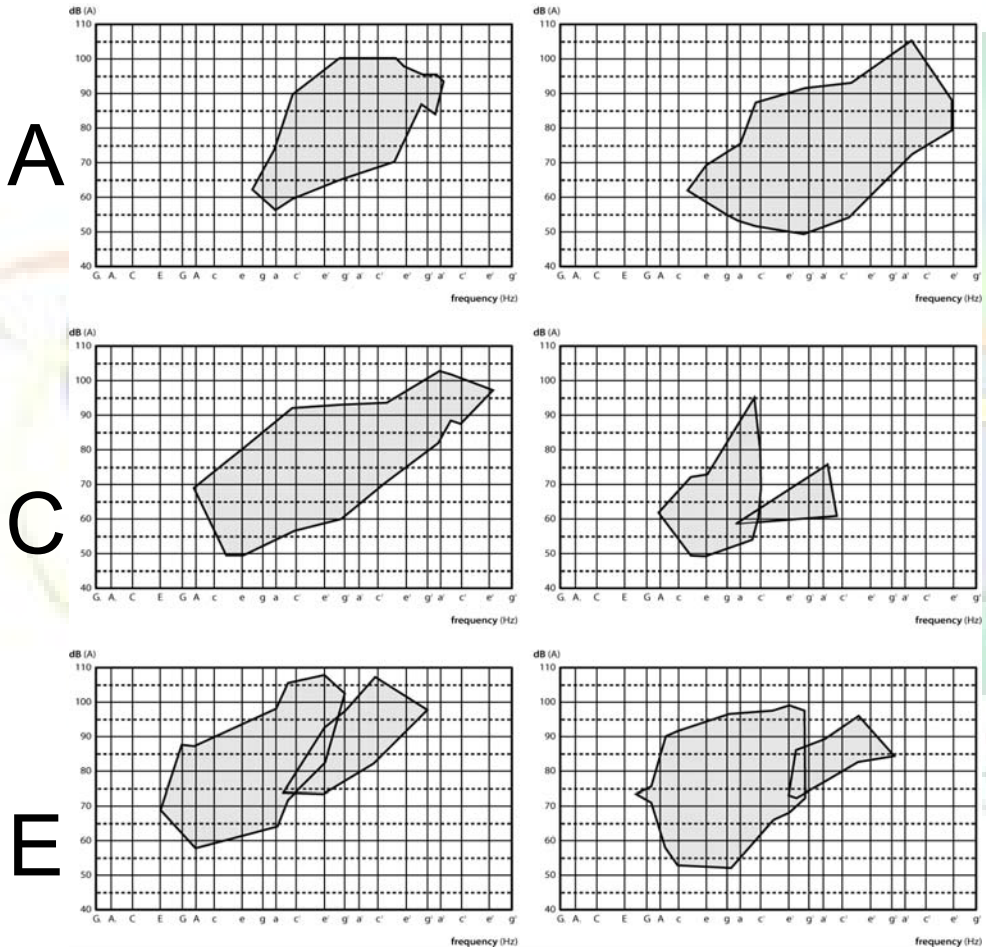
Development of fundamental frequency in girls



- Graphical representation of:
  - vocal parameters phonetogram areas,
  - tonal range of the speaking voice
  - tonal range of the singing voice
  - deepest note in the phonetogram
  - fundamental frequency of the speaking voice for girls as a function of age (abcissa):
    - (•) Breast development stage 1
    - (O) Breast development stage 2 – 4
    - (Δ) Breast development stage 5 - 6

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

Examples of phonetograms in boys before and after puberty

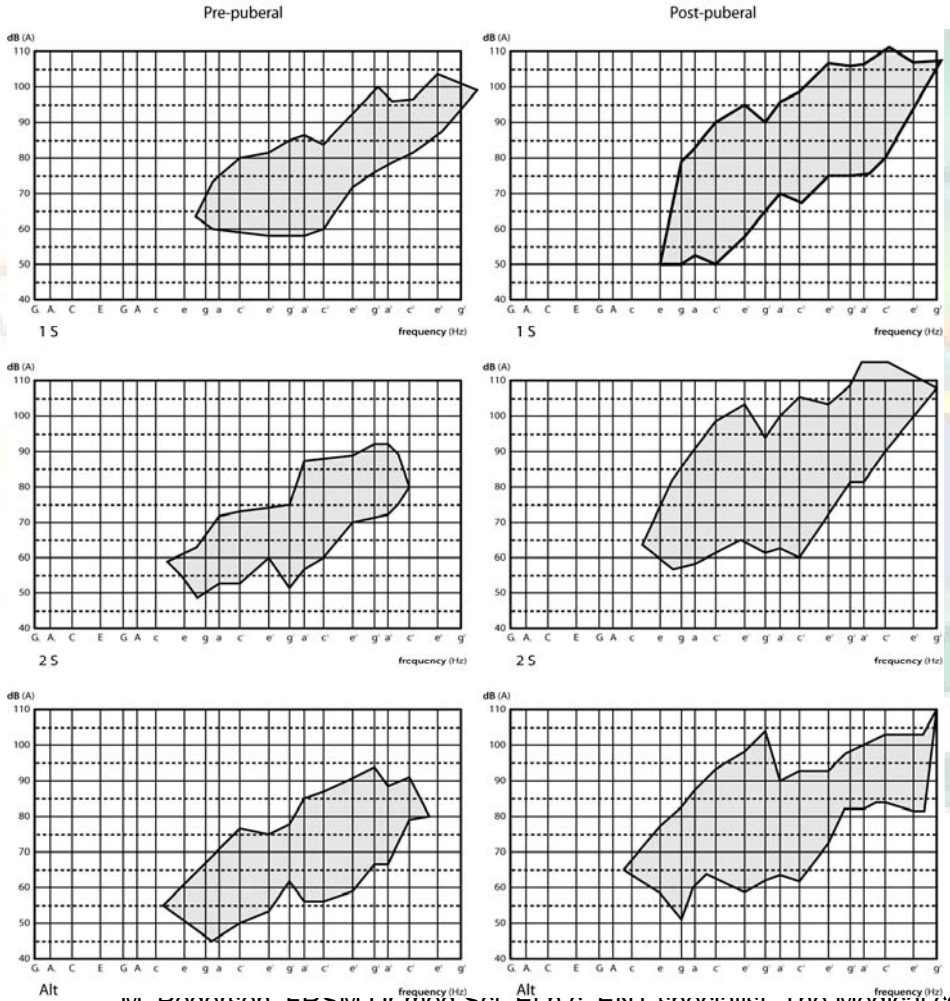


- Average phonetograms for boys and young men, depending on voice type. (The voice type was determined by the singing teacher.)

- **A:** Beginner
- **B:** Soprano
- **C:** Alto
- **D:** Voice in puberty
- **E:** Tenor
- **F:** Bass

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

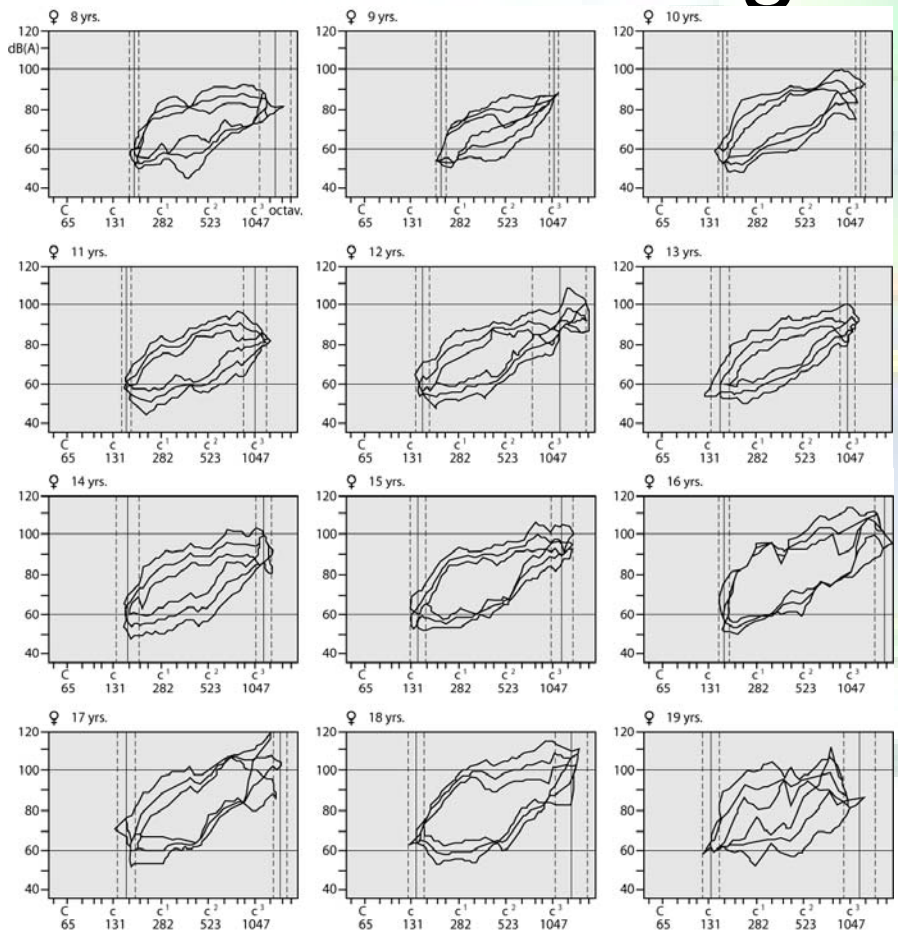
Examples of phonetograms in girls before and after puberty



- Phonetograms for girls of different voice types.
- In the upper frequency range, there is a bigger intensity for the sopranos, and in the lower frequency range for the altos.

M. Pedersen, FRSM Dr.med.Sci. Et n.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

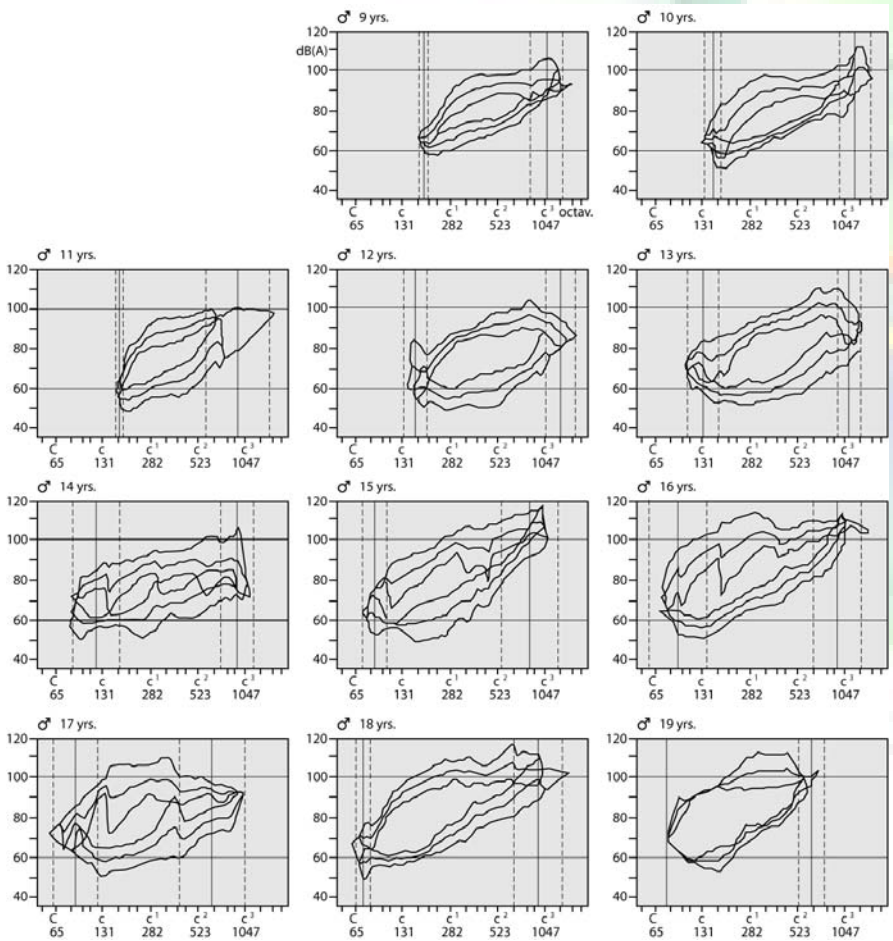
Average pr. year of phonetograms in girls



- Average phonetograms for girls with standard deviations, as a function of age.
- The abcissa is divided up into semitones, with the frequency in Hertz for each octave marked. The scale on the ordinate is in dB(A).

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

Average pr. year of phonetograms in boys



- Average phonetograms for boys with standard deviations, as a function of age.
- The abcissa is divided up into semitones, with the frequency for each octave marked.
- The scale on the ordinate is in dB(A).

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

Pubertal stage in boys

Age	(years)	8.7-12.9	13.0-15.9	16.0-19.5	pr yr. % change
No of boys		19	15	14	
Serum testosterone	(n mol/l)	0.54	10.5	18.9	68
Dihydrotestosterone	(n mol/l)	0.18	1.21	1.57	37
Free testosterone	(n mol/l)	0.007	0.14	0.33	77
Sexual hormone binding globulin	(n mol/l)	134	66	45	-16
Delta 4 androstene dione	(n mol/l)	0.54	1.17	2.5	24
Dehydro epi andro sterone sulfate	(n mol/l)	1400	4100	5900	25
Testist volume	(ml)	2.3	13	20	36
Fundamental frequency	(Hz)	237	184	125	-11
Voice range	(semitones)	3.7	4.8	5.0	3.9
Phonetogram area	(cm^2)	19	28	34	9.2
Lowest biological tone	(Hz)	158	104	72	-12

- *Geometrical average of hormonal, pubertal and vocal parameters for boys (grouped according to age) and the annual change in these parameters in %.*
- *(Phonetogram area:1 cm2 = 32 semitones x dB(A)).*

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

Pubertal stage in girls

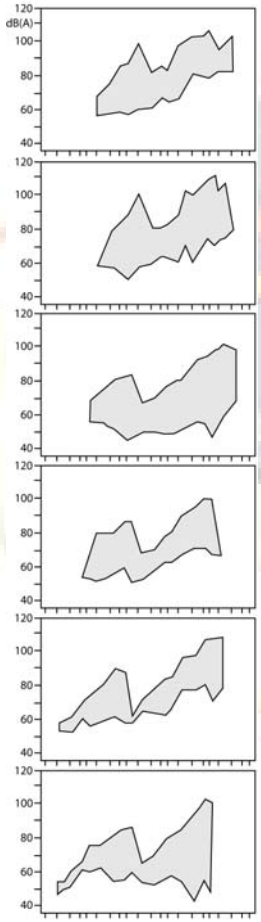
Age	(years)	8.7-12.9	13.0-15.9	16.0-19.8	Significance
Total number		18	12	11	
Oesterone (E1)	pmol	57	104	123	**
Oestradiol (E2)	pmol	73	135	108	
Total testosterone	nmol	0.5	0.76	0.94	
Free testosterone	nmol	0.006	0.037	0.009	
Oesterone sulphate (E1SO4)	pmol	732	1924	2342	**
DHEAS	nmol	3210	3700	7200	**
Androstendione	nmol	1.44	3.28	3.43	*
Sex hormone binding globulin (SHBG)	nmol	153	130	123	
Menarche		+4	+9	+11	
Pubic hair stage		1-4	2-5	4-6	
Mamma development stage		1-4	2-5	5	
Height		18	12	11	
Weight		57	104	123	
Fundamental frequency in continuous speech	Hz	256	248	241	
Tone range in continuous speech	Semitones	3.7	4.2	5.2	**
Tone range in singing	Semitones	23	30	38	
Phonetographic area	cm^2*	17.3	21.8	28.3	**
Phonetogram lowest tone	Hz	166	156	145	*
Phonetogram middle tone	Hz	429	409	413	
Phonetogram highest tone	Hz	1136	1105	1263	

* cm^2 conversion factor: 1 cm^2 = 32 semitones*dB(a).

- *Geometrical averages of hormonal, pubertal and vocal parameters for girls (grouped by age). The relative standard deviation lay between 11 and 140%.*
- *(Significance of the differences between the groups: p<0,01 xx; p<0,05 x).*

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

Pubertal development in a longitude study with measure every second month in the 8th school year, 3 boys

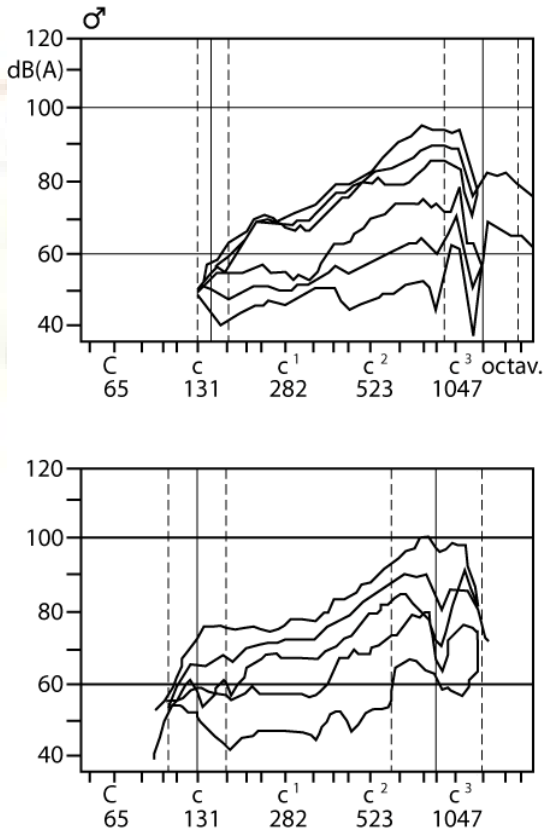


6 phonetograms, measured on a boy at intervals of 2 months (Age 13.7 - 14.6 years). The third phonetogram (December) has the biggest area and shows the smallest irregularities. In January, the boy was suspended from singing in the choir due to the start of the change of voice (C4 = 262 Hz).

M. Pedersen, FRSM Dr.med.Sci. Et h.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org

Statistics are necessary!

- The phonetograms of the Thomaner choir are different before puberty and in puberty



Average phonetograms with standard deviation for the cohort of sopranos and of pubertal change groups (mutants) from the Leipzig Thomaner choir. The hormonal parameters were similar to those of the Copenhagen boys.

.c. ENT specialist, The Medical centre, Østergade 18 3. DK – 1100 Copenhagen Denmark
Url:www.mpedersen.org