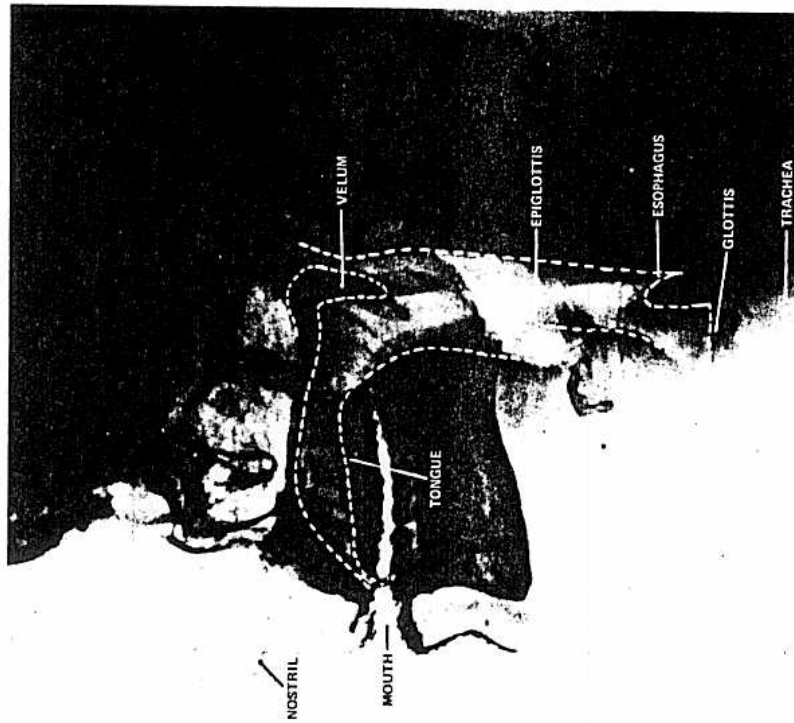


Schematic diagram of the human speech production mechanism (After Flanagan).

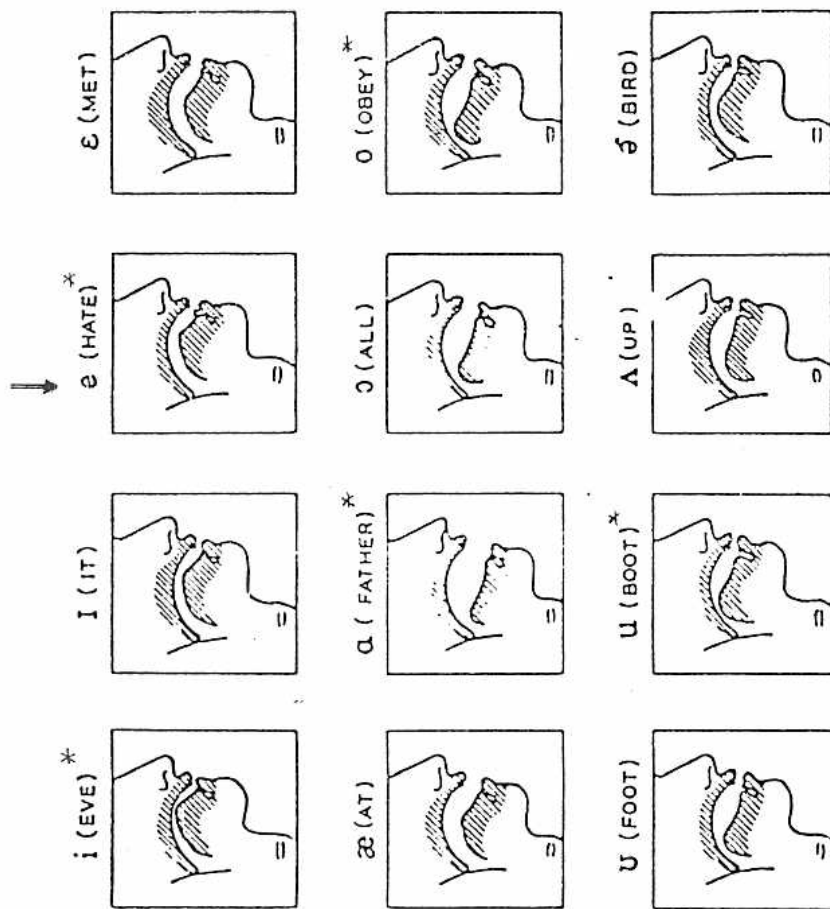


X-ray of a male vocal tract (After Flanagan).

The human vocal tract is a nonuniform acoustical tube that extends from the glottis to the lips. It is about 17 cm long in an adult male and therefore its first quarter-wave resonance occurs at a frequency given by

$$F_1 = \frac{1}{4} \frac{c}{l} = \frac{1}{4} \frac{34,000 \text{ cm/sec}}{17 \text{ cm}} = 500 \text{ Hz} \quad (12.1)$$

Its nonuniform cross-sectional area depends strongly on the position of the articulators and varies from 0 cm² at closure to about 20 cm². The vocal tract has certain normal resonant modes of vibration, called *formants*, that depend heavily on the exact position of the articulators.

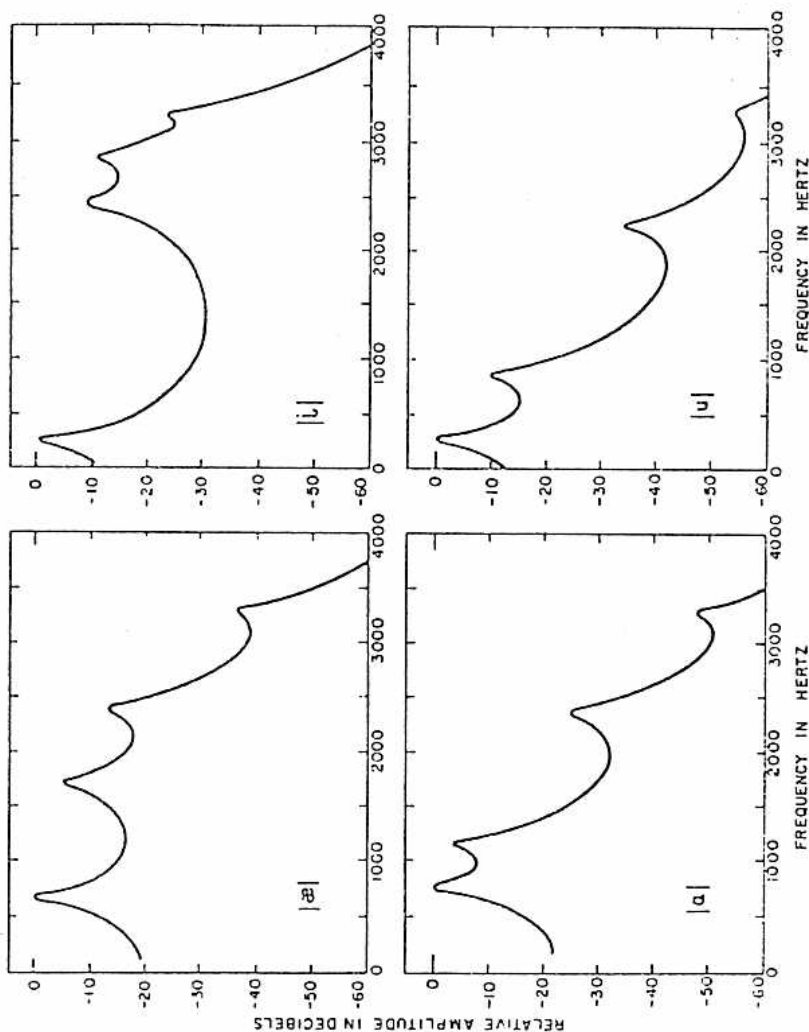


FORMANT FREQUENCIES FOR THE VOWELS

| Typewritten Symbol for Vowel | IPA Symbol | Typical Word | F_1 | F_2 | F_3 |
|------------------------------|------------|--------------|-------|-------|-------|
| IY | i | (beet) | 270 | 2290 | 3010 |
| I | ɪ | (bit) | 390 | 1990 | 2550 |
| E | ɛ | (bet) | 530 | 1840 | 2480 |
| AE | æ | (bat) | 660 | 1720 | 2410 |
| UH | ʌ | (but) | 520 | 1190 | 2390 |
| A | a | (hot) | 730 | 1090 | 2440 |
| OW | ɔ | (bought) | 570 | 840 | 2410 |
| U | u | (food) | 440 | 1020 | 2240 |
| OO | ʊ | (boot) | 300 | 870 | 2240 |
| ER | ɜ | (bird) | 490 | 1350 | 1690 |

Schematic vocal tract profiles and table of formant frequencies for several vowels

c (note)



Frequency transmission characteristics of several vowels

c (note)

Table 3.1 Phonemes in American English.

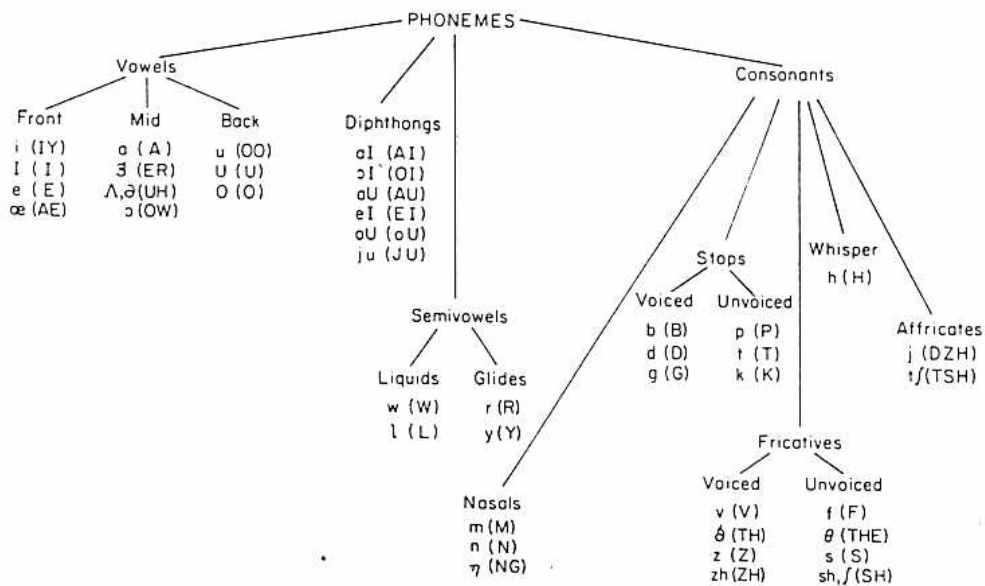


Table 3.2 Average Formant Frequencies for the Vowels. (After Peterson and Barney [11].)

| FORMANT FREQUENCIES FOR THE VOWELS | | | | | |
|------------------------------------|------------|--------------|----------------|----------------|----------------|
| Typewritten Symbol for Vowel | IPA Symbol | Typical Word | F ₁ | F ₂ | F ₃ |
| IY | i | (beet) | 270 | 2290 | 3010 |
| I | I | (bit) | 390 | 1990 | 2550 |
| E | ɛ | (bet) | 530 | 1840 | 2480 |
| AE | æ | (bat) | 660 | 1720 | 2410 |
| UH | ʌ | (but) | 520 | 1190 | 2390 |
| A | a | (hot) | 730 | 1090 | 2440 |
| OW | ɔ | (bought) | 570 | 840 | 2410 |
| U | U | (foot) | 440 | 1020 | 2240 |
| OO | u | (boot) | 300 | 870 | 2240 |
| ER | ɜ | (bird) | 490 | 1350 | 1690 |

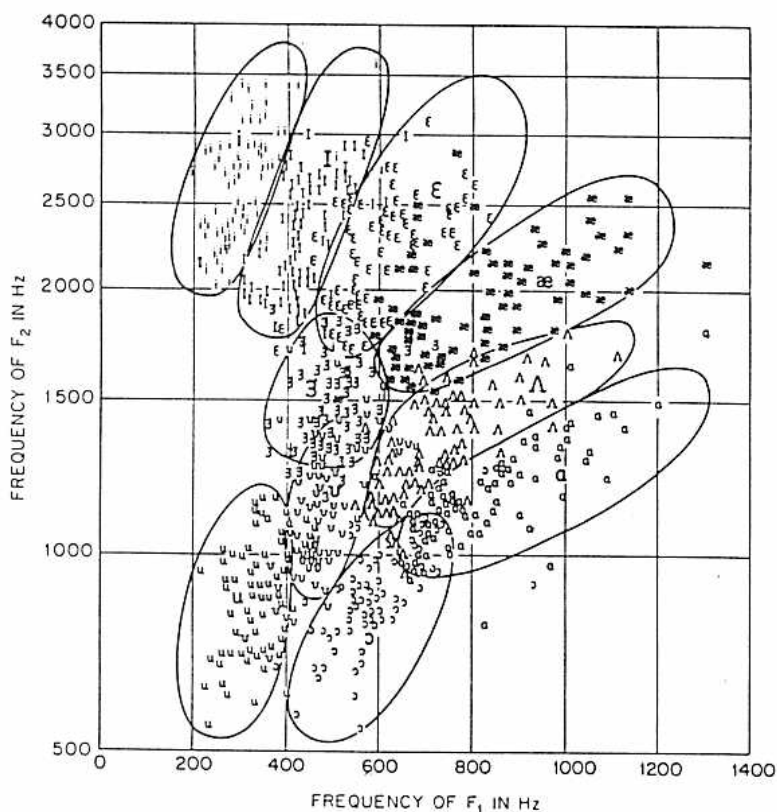


Fig. 3.4 Plot of second formant frequency versus first formant frequency for vowels by a wide range of speakers. (After Peterson and Barney [11].)

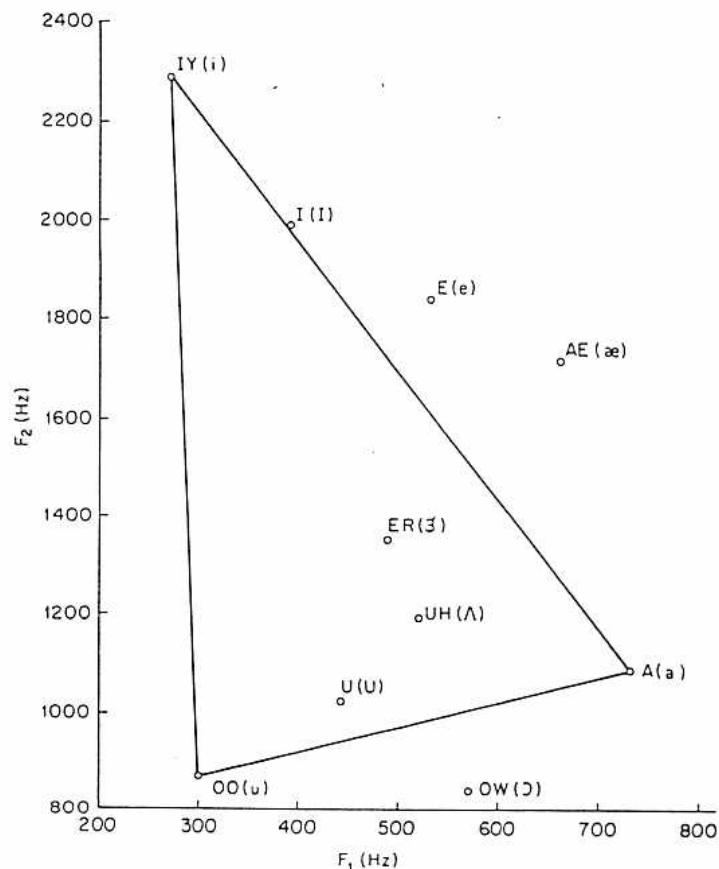


Fig. 3.5 The vowel triangle.