SINGING TECHNIQUES AND VOCAL PEDAGOGY

"Sine scientia ars nihil est"

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VOLUME TWO
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APPENDIX A: A BRIEF
CHRONOLOGICAL ACCOUNT OF
IMPORTANT VOICE SCIENTISTS,
SINGING TEACHERS AND THEIR
WORKS

A1: INTRODUCTION
This Appendix lists important people and events connected with the study of the singing voice. A chronological account which includes both scientists and musicians may appear odd at first sight, but this is probably the most useful approach for any reader who is unfamiliar with the historical aspects of this subject. I have tried to list all the influential sources up to the end of the nineteenth century, and a selection of important "landmarks" from the huge literature of the twentieth century. Chapter 2 is based upon the material listed here.

Specific events are listed under the relevant years; individuals are listed in order of their years of birth.

A2: B.C. - 1599
Aristotle (384 - 322 B.C.) showed in his works that vocal technique received more than passing attention. (Aristotle (A) and (B), quoted in Duey (1951.)

Quintillian (c 35 - 95 A.D.), the Roman orator and teacher of rhetoric, apprehended the essential requirements for the care of the voice. (Quintillian, c 95 A.D.)

Galen (130 - 200 A.D.), the Greek physician, described and named the larger cartilages of the larynx. He also called
the vocal cords the "glottis", or "tongue", and is often called the "founder of laryngology".

"Galen's works...were the ultimate medical authority for Europeans until the time of Vesalius [1514 - 1564] in anatomy and Harvey [1578 - 1657] in physiology."

(Asimov, 1975.)

John of Garland (c 1193 - c 1270) and Jerome of Moravia (c 1250) both divided the singing voice into three registers: chest, throat and head. (Duey, 1951, 33, and Large, 1973, 10.)

Franchinus Gaffurius (1451 - 1522), the Italian theorist and composer, said that singers should not bellow, or have a wide vibrato. (Gaffurius, 1496.)

1490: Leonardo Da Vinci (1452 - 1519) produced the first drawings of the cartilages, vocal cords and whole larynx in profile. (These studies have been compiled by Panconcelli-Calzia, 1943.) He believed that the voice was created in the windpipe. (Brodnitz, 1953, 22 and 25.)

Gioseffo Zarlino (1517 - 1590). An Italian theorist and composer, who wrote one of the most important works on music theory. (Zarlino, 1558.) This contains comments on singing styles.

1543: Publication of De Corporis Humani Fabrica by Andreas Vesalius (1514 - 1564). This had superb illustrations, many prepared by a pupil of Titian. (Asimov, 1975.) His diagrams of complete dissections of the larynx are hardly surpassed.
today in accuracy and detail. (Brodnitz, 1953, 22.)
(Vesalius, 1543.)

Cesare Pietro (1566 - 1625). An Italian theorist, singer and
priest, who worked mainly in Spain.

Danielle Friderici (1584 - 1638) was a German composer and
writer on music. His important work in the present context
is Friderici (1618).

Heinrich Schütz (1585 - 1672), the greatest German composer
of the seventeenth century. Duey (1951, 66) considers him to
be an important German source on singing. There were no
others until Johann Mattheson. (See below.)

1597: A work by Codronchi contained detailed work on the
larynx. (Codronchi, 1597.)

Giovanni Camillo Maffei (sixteenth century, dates unknown)
produced the earliest attempt at a complete singing method
in a letter to his teacher. (Maffei, 1562.) He was the first
"physiologist-musician".

A3: 1600 - 1699

1600: Publication of what is considered to be the earliest
surviving opera was in this year: Eurydice, by Pieri and
Caccini. Publication also took place of three works
containing detailed information on the larynx, by Julius
Casserius (1545 - 1616), (Casserius, 1600); Hieronymous
Fabricius (1537 - 1619), (Fabricius, 1600), and Caspar
Bauhinus (1550 - 1624), (Bauhinus, 1600).
1602: Publication of Giulio Caccini's famous work, *Le Nuove Musiche*. (Caccini, 1602.) Caccini (c 1546 - 1618) was a member of the Camerata, and an important early "operatic experimenter". He was also a singer and singing teacher, and his book contains the earliest reference to *messa di voce*.

Pierre-Benoît de Jumilhac (1611 - 1682), a French ecclesiastic and theorist, produced the only useful French singing manual in the seventeenth century, in the opinion of Duey (1951, 68). (See Jumilhac, 1673.)

Angeloni Bontempi (c1624 - 1705). A composer and singer, who described the plan of studies at the Papal singing school in Rome. He had a poor opinion of singers and teachers. He also wrote the first history of music in Italian. (Bontempi, 1695.)

Beninge de Bacilly (c1625 - 1690) was a choirmaster and teacher of singing. Duey (1951) says that he was the earliest of all French sources on singing. (de Bacilly, 1668.)

Antonio Francesco Pistocchi (1659 - 1729). An Italian composer, teacher, and brilliant castrato alto. Tosi thought him the best singer of all time. (See Fig. Al.)

Alessandro Scarlatti (1660 - 1725). Founded the Neapolitan School of opera. He was the greatest singing master of his time, and Nicolo Porpora was one of his pupils. (See Fig. Al.)
FIG. A1: TWO IMPORTANT SEVENTEENTH- AND EIGHTEENTH-CENTURY ITALIAN SCHOOLS OF SINGING

**Bolognese School**

Francesco Pistocchi (1659 - 1729)

- Antonio Maria Bernacchi (1685 - 1756)
  - Senesino (Francesco Bernardi) (c1680 - 1759) *
  - Alto castrato
  - Giovanni Carestini (1705 - 1760) *
  - Alto castrato

* See Appendix H for further details of these individuals

**Neapolitan School**

Alessandro Scarlatti (1660 - 1725)

- Nicolo Porpora (1686 - 1766)
  - Gaffarelli (Gaetano Majorano) (1703 - 1783)
    - One of the greatest castrati
  - Farinelli (Carlo Broschi) (1705 - 1782) +
    - The greatest castrato singer; sometimes called the greatest singer of all time
  - Regina Mingotti (1722 - 1808)
    - Austrian soprano
  - Caterina Gabrielli (1730 - 1796)
    - Eminent soprano. Also taught by the castrato Guadagni
  - Antonio Montagnana (Dates unknown)
    - A great bass, for whom Handel composed arias
  - Domenico Corri (1746 - 1825)

+ See section D2 for further details of Farinelli
1674: John Mayow and others began investigating breathing. Before this time, breathing was generally thought to cool the blood, and so this is an important date for vocal science. (Proctor, 1980, 11.) Mayow (1640 - 1679) died young, and it remained for Lavoisier to consolidate his ideas.

**Johann Mattheson** (1681 - 1764). A German singer, composer and theorist; a friend of Handel.

"...Mattheson's writings cannot be adequately summarized. In more than a dozen major volumes and a number of smaller publications, he discussed almost every aspect of the music of his day." (Sadie, 11, 835.)

See, for example, Mattheson (1739.)

**Jean Philippe Rameau** (1683 - 1764). The French composer and theorist, and an important source. (See Rameau, 1760.)

**Antonio Bernacchi** (1685 - 1756) was an alto castrato. Porpora led a reaction against his extravagant method, but Farinelli studied under him in 1727.

**Nicolo Antonio Porpora** (1686 - 1766). A pupil of Scarlatti and a great opera composer and singing-master. He is considered by many to have been the greatest of all singing teachers, having taught many of the most celebrated eighteenth-century singers. (See Fig. 11.) Porpora never wrote an account of his methods, but many have claimed to know them. George Sand wrote a novel about Porpora's singing school, *Consuelo*, which Mackenzie (1890, 114) said was based
upon careful literary research. (Sand, 1847.)

Leonardo Leo (1694 - 1744). A very influential Italian composer and teacher.

1694: John Playford (1623 - 1686) published a book which contains some important comments on singing. (Playford, 1694.)

A4: 1700 - 1799

1703: Vennard (1968, 310) considers a book published by Dodart in this year, together with Ferrein's work (see below) to be the earliest works on the voice which are "scientific" in the modern sense. (Dodart, 1703.)

Friedrich Wilhelm Marpurg (1718 - 1798). A German critic, theorist and composer, and an important German source on singing.

1723: Pietro Tosi (c1653 - 1732) wrote a famous book on singing, which deals more with style than technique. (Tosi, 1723.)

Dr Charles Burney (1726 - 1814). The English organist and writer on music. The accounts of his travels on the continent give invaluable information on many aspects of singing. (See, for example, Burney, 1776 - 1789.)

Johannes Adam Hiller (1728 - 1804). A composer and writer on music, and the best singing teacher of his time, according to Shakespeare (1924, 78). He was the "father" of the
Singspiel form.

"His writings on singing reveal an excellent teacher, well versed in both the theoretical and practical aspects of the subject." (Sadie, 8, 566).

See Hiller (1774), a work described by Monahan (1978, 258) as equalling or surpassing any other of the time.

**Giuseppe Aprile** (c1731 - 1813) was an Italian castrato contralto and singing teacher. He was famous both as a singer and the teacher of the tenor Michael Kelly, Mozart's friend. (Bacon, 1824, Appendix II.) (See Aprile, 1791.)

**Gasparo Pacchiarotti** (1740 - 1821). The last great castrato soprano. A singing method by him was adapted and published by Calegari (1836). Pacchiarotti taught Francesco Bennati.

1741: The publication of Ferrein's classical work. (Ferrein, 1741.) He first used the term cordes vocales (Brodnitz, 1953, 22.)

"Before the experiments of Ferrein in 1741 the theories of phonation were based on the incorrect speculations of Galen and even after this time there is considerable doubt that Ferrein's theories were ever instrumental in affecting teaching methods." (Duey, 1951, 153.)

(Ferrein demonstrated the vibrating action of the vocal cords, using the excised larynx of a dog.)

1756: An important French source by Jean Blanchet (1724 - 1778),
"...presents a simple description of the action of the chest, lungs, and diaphragm in breathing..." (Duey, 1951, 84.)

(Blanchet, 1756.) Duey (1951, 89) considers that in this period, French sources appear to be the most scientifically analytical about the singing process. Statements about physiology are often inaccurate, however.

1757: A work by Johann Friedrich Agricola (1720 - 1774) gives the most complete eighteenth-century exposition of phonation theories. Agricola was a pupil of J. S. Bach, and his wife was a wonderful soprano.

Giacomo Gotifredo Ferrari (1763 - 1842). An Italian opera composer and singing-master in London. (Ferrari, 1818.)

1767: Jean Jacques Rousseau's Dictionnaire de Musique (see Rousseau, 1779) contained some important ideas and definitions pertaining to the voice, and an article entitled Goût du chant.

1771: Anselm Bayly (1718/19 - 1794) listed the important steps in the teaching of singing, and provided a good summary of other writers' views on breath control. (Bayly, 1771.)

1774: The discovery of oxygen by Joseph Priestley (1733 - 1804).
Giovanni Battista Mancini (1716 - 1800). Considered by Duey (1951, 62) to be a better bel canto source than Tosi (1723). (Mancini, 1774.)

Manuel Garcia the elder (Manuel del Popolo Vicente Rodriguez Garcia), (1775 - 1832). He was a Spanish tenor and composer, and the principal exponent of Rossini's vocal music outside Italy. His four children were all singers (see Fig. A2). The youngest, Manuel Garcia, was the greatest singing teacher of the nineteenth century; he followed in the footsteps of his father, who was also a gifted teacher. The elder Manuel wrote a book of standard singing exercises. (Garcia, 1868). These are typical of the many books of vocal exercises, or solfeggi, produced in the eighteenth century and slightly later. (See also notes on Vaccai, Concone and Viardot.)

1779: Lavoisier (1743 - 1794) first used the word "oxygen", as a result of work following Priestley's visit to him in 1774. Lavoisier later realized what part oxygen played in respiration.

Niccolo Vaccai (1790 - 1848). An Italian composer and singing teacher whose vocal exercises are still in common use. (See Vaccai, 1832 and c1840.)

1791: Wolfgang von Kempelen made further advances upon Ferrein's theories about the vibration of the vocal cords. (Browne & Behnke, 1980, 112.) (von Kempelen, 1791.)
FIG. A2: THE GARCIA FAMILY AND TWO OF ITS FAMOUS PUPILS

Manuel Garcia the elder (1775 - 1832)
- Josepha Garcia (Ruiz-Garcia) A little-known singer
- Maria Felicia Garcia (Malibran) (1808 - 1836) A great contralto
- Michelle Pauline Garcia (Viardot or Viardot-Garcia) (1821 - 1910) A great mezzo-soprano
- Manuel Garcia the younger (1805 - 1906)
  - Jenny Lind ("The Swedish Nightingale") (1820 - 1887) Garcia gave Lind exercises for her medium register when she went to him in Paris in 1841 to "mend her worn and uneven voice". (Klein, 1923, 16. See also Garcia, 1894, 29.)
  - Herman Klein (1856 - 1934) Klein studied with Garcia for four years. The elder Garcia was alive during Mozart's lifetime, and so the younger Manuel was taught by someone with a supposed first-hand knowledge of the singing techniques used by Mozart's contemporaries. Klein uses this fact as evidence for the authenticity of his own work (Klein, 1923) and implies that the younger Manuel knew a great deal about the old bel canto techniques. Klein also edited Garcia (1894).
- Gustave Garcia (1837 - 1925) Son of Manuel. An operatic baritone and teacher of singing at the Royal Academy and Royal College of Music.

1797: Vincenzo Manfredini (1737 - 1799). A useful source on bel canto. (Manfredini, 1797.)

A5: 1800 - 1853

1800: Maria Anfossi (late eighteenth century) wrote a treatise on singing technique which is one of the most descriptive of its time. (Anfossi, 1800.)
Giuseppe Concone (1801 - 1861). An Italian composer and singing teacher who published many books of vocal exercises. Some of these are still in common use.

1803: Nina D'Aubigny von Engelbrunner (dates unknown), the German composer, wrote a book which is considered outstanding by Monahan (1978, 223). (See D'Aubigny von Engelbrunner, 1803.)

1806: René Dutrochet compared the action of the vocal cords with that of the lips when playing a horn. (Browne & Behnke, 1890, 112.) (Dutrochet, 1806.)

1807: Jean Baptiste Joseph Fourier showed that any periodic oscillation (a sound wave, for example) can be broken down into a series of simple regular wave motions. It can also be represented as the sum of a number of simple, pendular undulations. (Vennard, 1968, 5. However, Vennard attributes this theory, wrongly, to the year 1822.)

1811: Domenico Corri (1746 - 1825) wrote a book detailing Porpora's techniques. He was a student of Porpora's for five years, and later became a composer and singing-master in London. (Corri, 1811.)

1813: Gesualdo Lanza (1779 - 1859) wrote an important book on singing. He was an Italian singing-master who worked in London. (Lanza, 1813.)
Francesco Lamperti (1813 - 1892). Allegedly the last exponent of the old bel canto traditions, he retired in 1876.

1814: A book on voice production by the scientist, Carl Liskovius. (Liskovius, 1814.) He thought that the pitch of the voice depended upon the size of the slit between the vocal cords. (Browne & Behnke, 1890, 112.)

Pauline Viardot (1821 - 1910). The great mezzo-soprano and sister of Manuel Garcia the younger. Some of her vocal exercises are still in common use. (See Viardot, 1861.)

Madame Mathilde Marchesi (1821 - 1913). Her writings (e.g. Marchesi, 1902) are quoted often by other writers.

1824: An important book by Richard Mackenzie Bacon. (Bacon, 1824.)

"...a work of undeniable merit, and appeared at the culmination of one of the great golden ages of singing..." (Introduction to 1966 edition, p iv.)

Bacon (footnote to pp 60 and 61) quotes an anecdote which seems to pre-empt, in a limited way, the work of Wheatstone, Helmholtz and others on acoustics. Bacon appears to be referring to what we would call partials:

"In conversation with a friend of very acute parts, great learning and fine taste, (but no musician), he threw out a conjecture that tone, like light, may be composed of parts indivisible as the rays, though no musicometer similar in effect to the prism has yet
been discovered. To the absence of some of the rays of sound he imagined differences in tone might be owing. The idea is fanciful, and to me new -- therefore I repeat it; but I apprehend organic or mechanical circumstances are quite sufficient to account for all the different powers and qualities of tone evinced by singers."

No other writer, to my knowledge, has pointed out the possible significance of Bacon's statement.

1825: A publication on voice production by the scientist Felix Savart. (See also Couvier, de Prony & Savart, 1832.) He thought that the ventricles of Morgagni were important in voice production. (Browne & Behnke, 1890, 112.)

1830: A publication on voice production in singing by the scientist, physician and surgeon, Francesco Bennati. (See Bennati, 1830, and subsequent works: Bennati, 1832 and 1833.) Bennati was trained by Gasparo Pachierotti.

1831: A work on voice production by the scientist Malgaigne. (See Colombat, 1836.) He made further observations about vocal cord vibration. (Browne & Behnke, 1890, 122.)

1832: A work on voice production by the scientist Sir Charles Bell. (Bell, 1832.)

1833: A work by Bennati contained some important ideas on covered singing: see section 6.7.4. (Bennati 1833.)
1835: Carolus Lehfeldt noticed the differences in the vocal cords during the production of the chest register and the falsetto. (Browne & Behnke, 1890, 112.) (Lehfeldt, 1835.)

1836: Isaac Nathan (1790/2 - 1864), the English composer and tenor, published Musurgia Vocalis. A's Monahan (1978, 274) has said,

"[this] is perhaps the most complete work of its time, not only as a singing instructor, but as a history and theory book."

Nevertheless, the language is complex, and Nathan delighted in unusual anecdotes and difficult philosophical ideas. I do not think that this book is widely-known. For example, the copy supplied to me by the British Library appeared to have been issued last in 1928!

1837: Wheatstone formulated his theory of vowel formants. (See Wheatstone, 1837.) (See also sub-section 6.7.2.)

In the same year, Johann Müller noticed that the frequency and intensity of sound depend primarily upon the tension of the vocal cord folds and the subglottic air pressure. (Müller, 1837, quoted by Large, 1973.)

"[Müller's] brilliant chapter on the voice has been the locus canonicus on which nearly all succeeding writers have founded their doctrines." (Mackenzie, 1890, 241.)

1838: François Magendie carried out experiments upon living dogs whose larynges were exposed. (Browne & Behnke, 1890,
Magendie was a prolific writer on medical matters.

1839: Müller carried out exhaustive experiments on excised larynges. He concluded that pitch is independent of the length of the vocal tract. (Browne & Behnke, 1890, 113-114). (Müller, 1839.)

1840: A paper by Diday & Pétrequin was an important landmark in relation to covered singing: see section 6.7.3. (Diday & Pétrequin, 1840.)

1847: First complete edition of Manuel Garcia's immensely influential work. (Garcia, 1847.) There is confusion about the date of the first edition. I have seen it given as 1840 and 1856, but 1847 seems to be correct. (This confusion is due partly to the fact that Part One was published separately in 1840 - see Garcia, 1840 - and also partly to revisions being treated as new works.)

Garcia (1805 - 1908) stated that the primary source of sound is provided by periodic air puffs which set the air vibrating above the glottis. This was confirmed by Helmholtz. (Helmholtz, 1863.)

Garcia retired from singing as a baritone in 1829, and then did administrative work in military hospitals in France, where he studied vocal physiology. (See Fig. A2.)

Lilli Lehmann (1848 - 1929). A great singer and writer of an influential book which nevertheless is very arrogant and contains many errors, some of which are discussed elsewhere.
in this work. (See Lehmann, 1902.)

William Shakespeare (1849 - 1931). The greatest English singing teacher of his day, and very influential. He was a concert and oratorio singer, and took daily lessons from Lamperti in Milan for two years. He wrote two important books. (See Shakespeare, 1899 and 1924.)

A6: 1854 - 1899

1854: The laryngoscope was "invented" by Manuel Garcia in the Autumn of this year. (Brodnitz, 1953, 1.) However, there had been at least nine previous recorded attempts to produce a similar instrument. (Browne & Behnke, 1890, 115 - 116; and Moore, 1937, 531-534.) These were made by Bozzini (Frankfurt-am-Main, 1807); Senn (Geneva, 1827); Babington (London 1827); Cagnaird de la Tour (1829); Bennati (Paris, 1832); Beaumes (Lyons, 1838); Liston (London, 1837); Avery (London, 1840), and Warden (Edinburgh, 1844).

Garcia was the first person to demonstrate the instrument successfully and to realize its potential; he is therefore credited with its effective invention. His original ideas were received with little enthusiasm, but the effect of this instrument upon singing and medicine has been profound. In fact, the whole course of vocal science was changed immediately by the ability to view the vibrating larynx. Whether this was a good or bad thing was disputed hotly by later nineteenth-century writers, but it cannot be doubted that this was probably the single most important event in the whole history of the study of the voice. (Garcia's findings were reported by Dr Sharpey: see Garcia, 1855.)
Garcia's instrument may not have enjoyed such rapid success without the help of its champions, Turck in Vienna, and Czermack. (See below.)

(See Fig. A2 for details of Garcia's family and some of his pupils.)

1855: An article by Louis Mandl was considered to be of great importance by Mackenzie (1890, 88), although Mandl's ideas on breathing appear to have been mistaken. (See subsection 3.2.4.) However, Taylor (1908, 23) considers that Mandl (1876) first put forward breath control as a definite principle of vocal science.

1856: Mary Sabilla Novello ( ? - 1904) wrote Voice and Vocal Art (1856), which is considered outstanding by Monahan (1978, 223). She was the daughter of Vincent Novello and a soprano, but known mainly through her books on the voice. (Novello, 1856.)

1858: Professor J. Czermack of Budapest invented the head mirror, a vital adjunct to the laryngoscope. (Brodnitz, 1953, 122.) Czermack was the teacher of Sir Morrell Mackenzie, (see below), and a missionary for the laryngoscope. Mackenzie (1890, 13) says that Garcia's observations would have remained in oblivion without him. He was also a pioneer in the photography of the larynx.

1861: The first German edition of Emma Seiler's well-known book on singing. She was a pupil of Helmholtz, and her book is grounded on his work and that of Garcia. (Seiler, 1868.)
1863: The first edition of Hermann von Helmholtz's work, later translated as On the Sensations of Tone... (Helmholtz, 1875.) This was a landmark in the study of sound, and Helmholtz's views on resonance were taken up quickly by others. As Vennard (1968, 17) has said, late nineteenth- and early twentieth-century investigators were preoccupied with resonance, whereas the study of the vibratory mechanism itself has been mainly a twentieth-century phenomenon.

1866: First edition of Charles Lunn's Philosophy of Voice, (Lunn, 1900). This is an astonishing book, and amongst the most arrogant and dogmatic treatises ever written on the voice. Lunn was taught by Vencesleo Cattaneo, who claimed to use Nicolo Porpora's methods of teaching, and Lunn assumed himself to be the leading, if not the only, authority on the singing voice. His book was widely-quoted by other authors and very influential, perhaps because of his dogmatic stance. It is worth considering some of his comments. (Lunn claimed to have been an exceptional singer, with a range of nearly three octaves; if this is true, his was certainly a rare talent!)

"My discovery of the natural physics of voice, which settled controversy for ever, has been before the world thirty years; it has never been disproved, and no other logical explanation is or can be given."

(Lunn, 1900, p xii.)

A dangerous claim!

"It is my privilege to explain away their [unscientific vocalists and the like] differences, correct their errors, and raise their standard."

(Lunn, 1900, 5.)
Lunn was no lover of the laryngoscope as a tool for examining the vocal cords whilst singing, and rightly said that it is impossible to sing properly with a laryngoscope in position. (Lunn, 1900, 163.) This is one of the major points in his book. On the other hand, his attempt to compare the voices of birds and mammals is quite unfounded in zoological terms. Galen apparently knew the correct action of the laryngeal ventricles, but Lunn rediscovered this! (Lunn, 1900, 82.)

Despite the bigotry and inaccuracies, this is a fascinating book, but it must be treated cautiously in view of Lunn's pique:

"In 1880 Messrs. Browne and Behnke usurped my position as scientific authority on the voice, and, to destroy my explanation of artistic production as learned by me on the old basis, put out a number of pictures of a distorted throat effortfully emitting unmusical and uncontrollable noises." (Lunn, 1900, 176.)

Lunn published several other books, including one in 1884 which aimed solely to refute the claims of Browne and Behnke. (See Lunn, 1884.) However, none of his other works is as well-known as the one discussed here.

1867: The publication of a strange book by Alexander Melville Bell called Visible Speech. (Bell, 1867.) This explained a system for writing all languages in one alphabet, and is praised by Paget (1930). It is mentioned here, as it was symptomatic of a late Victorian and
Edwardian interest in phonetics. (See also Ellis, 1878, and Mott, 1910.)

1871: An important book on laryngeal anatomy and physiology by Hubert von Luschka, Der Kehlkopf des Menschen. (The Human Larynx.) (Luschka, 1871.)

1873: An important book on laryngeal anatomy and physiology by Merkel, Der Kehlkopf. (The Larynx.) (Merkel, 1873.)

1878: Alexander Ellis's Speech in Song. This is probably the most detailed, scholarly and complex book which I have encountered during my researches. The information on phonetics and linguistics is phenomenal. Ellis was a true expert: he translated Helmholtz's work (Helmholtz, 1875) and is mentioned in the preface to Shaw's Pygmalion. (Ellis 1878.)

1879: Holmes's book, A Treatise on Vocal Physiology and Hygiene, was considered to be very important by many writers. For example, see Lunn (1900, 147-148.) (See Holmes, 1879.)

c. 1880: Professor F. C. Donders of Utrecht noticed that each vowel when whispered causes resonance in the mouth and throat at different pitches. William Aikin (1910) and Paget (1930) also demonstrate this. (Similar ideas were given by Ellis, 1878, and Helmholtz, 1875, but see Mott's comment at the end of sub-section 6.7.2.)
1883: First edition of the work by Lennox Browne and Emil Behnke. (Browne & Behnke, 1890.) Browne was a surgeon and Behnke a singing teacher; together they made a formidable team and their publications were very influential. They had certain ideas, which may have been misguided, to which they adhered firmly. Nevertheless, as anatomical and medical books, their works are impressive. (See also Behnke, 1882, and Browne, 1876.) They incurred the furious wrath of Lunn (see above).

Behnke's daughter, Kate Emil Behnke, took up his mantle and published several books.

1886: First edition of one of the most famous and best-remembered nineteenth-century books on the voice: Sir Morrell Mackenzie's *The Hygiene of the Vocal Organs*. (Mackenzie, 1890.) Mackenzie was the best-known English throat specialist of his time, and set himself up as the authority on the voice. He disagreed with Garcia's views on the value of the laryngoscope to singing teachers, and said, quite justifiably, of such users:

"It is hardly too much to say that no two of them quite agree as to what is seen." (Mackenzie, 1890).

1894: Publication of the English edition of Garcia's second famous book, *Hints on Singing*. This was written in his ninetieth year, and edited by Hermann Klein. (Garcia, 1894.)

1896: G. E. Thorp wrote two important and influential books on singing (Thorp 1896A and 1896B), and a third book with W. Nicholl (Thorp & Nicholl, 1896). These books contain
interesting exercises for developing various aspects of the voice.

1898: The publication of a useful book on singing by Rowley, which contains summaries of various theories relating to the voice. (Rowley, 1898.)

A7: 1900 - 1983

1906: The publication of F. Mathias Alexander's pamphlet on vocal re-education. (Alexander, 1906.) Alexander was the inventor of the Alexander Technique, a postural and relaxation method widely used by performers. Although Duarte (1981, 6, and 7) has said that this is a "somewhat confusing plan for vocal re-education", I consider Alexander's ideas as a whole to be of supreme importance in singing. This is discussed in section 3.1 and Appendix B. (See also Alexander, 1932, and Barlow, 1973.)

1908: A valuable book was published by Taylor which contains some interesting ideas on the mechanical aspects of singing. (Taylor, 1908.) I have discussed some of these ideas in another work, and built a piece of apparatus which he suggested (White, 1982B). (See also sub-section 3.2.3.)

Taylor was unwise in giving this prediction:

"So far as the muscular operations of tone-production are concerned, and the laws of acoustics bearing on the vocal action, no new discovery can well be expected." (p viii.)

This is on a par with some of Lunn's statements (see above).
1909: Publication of Ernest George White's book, Science and Singing. (See White, 1938A) I discuss White's incorrect, but influential, ideas on sinus tone production in section 4.4. (See also White, 1931 and 1938B.)

1910: Mott's book contains much detail of phonetics, following in the late Victorian tradition of Ellis (1878). (Mott, 1910.)

1923: Nadoleczny's study of vocal registers is one of the most comprehensive ever published. (Nadoleczny, 1925.) It contains a classical study of breathing in singers. (Brodnitz, 1953, 80.)

1925: Tonndorf said that the Bernouilli effect assists the elastic recoil of the vocal folds. (Tonndorf, 1925.)

1929: The publication of an oft-quoted work on the larynx by Negus. (Negus, 1929. See also Negus, 1949.) Negus is probably the greatest authority on the comparative anatomy and physiology of the larynx.

1930: Publication of Sir Richard Paget's famous book, Human Speech. This is considered by many writers to be a landmark in the study of phonetics and linguistics.

1930's: This decade saw the publication of some important works by Carl Seashore and his colleagues at the University of Iowa. There are numerous papers, published over a period of years. Many are concerned with vibrato and related
phenomena, but the classical work on vibrato, in my opinion, appeared in 1936. (Seashore, 1936.) Although performed on relatively primitive apparatus, Seashore's work is astounding and still largely valid. This is referred to extensively in sections 6.2 and E1.

1933: Publication of an influential book by the English teacher, Charles Kennedy Scott (Scott, 1933). This book is quoted widely, but volume one contains numerous errors and strange ideas, amongst which are the following:

"All our vowels are modifications of the consonant m." (p 8.)

"The expiratory muscles of the diaphragm..." (p 44.)

(See section Cl.)

There are some useful ideas on singing in volume one, which are lost amongst philosophical and subjective ideas, an unscientific approach, and appalling analogies. Volume two contains some excellent singing exercises, especially for articulation. These may explain why some people think so highly of this book.

1934: Bartholomew enumerated the characteristics of the bel canto voice in a scientific manner. (Bartholomew, 1934.)

1940: Dr D. W. Farnsworth produced the now-famous Bell Telephone film of the vocal cords in motion. (Farnsworth, 1940.) This had a profound effect upon thinking related to voice production.
1940's: Wallace Fenn et al, at the University of Rochester, brought the field of breathing mechanics into an orderly organized body of knowledge. (Proctor, 1980, 12.)

1950: Husson first formulated his revolutionary neurochronaxic theory of voice production. (Husson, 1950.) This is now discredited, but is discussed in detail in section 4.3.

1953: The publication of a valuable and detailed reference work on speech and hearing by Fletcher. (Fletcher, 1953.)

1958: van den Berg's paper was an important landmark in vocal science. His myoelastic-aerodynamic theory of voice production is now the generally-accepted view. This is discussed in 'section 4.3. (van den Berg, 1958.)

1959/1960: Proctor (1980, 12) considers that papers published in these years by Draper, Ladefoged and Whitteridge mark the transition towards the contemporary understanding of phonation. (Draper, Ladefoged & Whitteridge, 1959 and 1960.)


1965: A book by Luchsinger and Arnold is a vital source of reference for any research worker studying the scientific aspects of voice production. (Luchsinger & Arnold, 1965.)
1966: A Symposium on Sound Production in Man at the New York Academy of Sciences summarized the current state of knowledge of this subject. (See Bouhuys, 1968.)

1967: An important book on singing teaching by Appelman. This is full of anatomical and physiological details, but Appelman's methods tend to be frowned upon by contemporary teachers and research workers. (Appelman, 1967.)

The same year saw the publication of the revised edition of a very useful book on singing by Vennard. This is a valuable source of reference in research work. (Vennard, 1968.)

1968: The publication of a useful book on the medical aspects of lung function by Cotes. (Cotes, 1968.)

1970's: The publication of some key works on vocal acoustics by Johann Sundberg. (Sundberg, 1974, 1975 and 1977.) In his papers, Sundberg presents the most coherent ideas on vocal acoustics which are tenable with our present state of knowledge. Most other serious modern theorists seem to be in general agreement with his ideas.

1972: A Symposium on Ventilatory and Phonatory Control Systems at the Royal College of Surgeons summarized the current state of knowledge of this subject. (See Wyke, 1974.)

pedagogy, Manén has interesting and fairly unconventional ideas on how the voice is produced. Her work is referred to extensively in the present study. (See also section 7.5.)

1976: An influential book by Husler and Rodd-Marling, which is essentially for teachers, and contains detailed anatomical and physiological material, some of which is very inaccurate indeed. (Husler & Rodd-Marling, 1976.) This book has exerted a considerable influence over many British teachers, and it contains many useful exercises. However, it also contains some dubious pseudo-scientific ideas on various topics.

1982: The publication of an interesting and useful book by Butenschön & Borchgrevink. This contains an unique discussion of the "dorsal method" of singing (see sub-section 3.2.2) and many unusual anatomical and physiological facts. (Butenschön & Borchgrevink, 1982.) However, this book contains what I consider to be a supreme example of a ridiculous exercise:

"...Pinch the corners of your mouth almost together from the sides, using the thumb and middle finger, at the same time pressing the cheeks in between the teeth. Put the index finger up behind the upper lip to prevent the lip from being tensed [my emphasis]." (p 19.)

1983: A book by Bless & Abbs contains several important papers which shed new light on many aspects of voice production. (Bless & Abbs, 1983.)
APPENDIX B: THE ALEXANDER TECHNIQUE AND RELATED POSTURAL IDEAS

B1: INTRODUCTION

This Appendix is provided primarily for readers who are unfamiliar with the Alexander Technique.

Several quotations in Chapter 2 are from an important paper written by the great anthropologist, Raymond Dart, who took lessons from an Alexander Technique teacher who revealed his bad postural habits. Dart still works part-time in an institute in Philadelphia with brain-damaged and retarded children, using his postural techniques and those of Alexander (see below).

Dart makes an important distinction between poise, and attitude or posture. The latter terms, he says, refer to both good and bad habits, but poise, by definition, refers to an ideal set of habits. It is enough, then, to say that we should all aim to achieve poise:

"...the use of the body in proper poise insures the least friction with consequently the greatest amount of energy available for what may be required of the individual." (Goldthwait, et al, 1945.)

"...the static symbolism of posture...the dynamic plasticity of poise..." (Dart, 1947, 74.)

Why should Man's posture be so universally poor? Basically because he is imperfectly adapted for an upright stance: his
body developed for other modes of locomotion. Further, Dart believes that malposture is causally related to the intensification of civilized life during the last century. (Dart, 1947, 74.) Books like The Naked Ape (Morris, 1967) have made people aware of the mechanical problems of an upright stance.

We suffer from the idea that correct posture, or poise, is that encouraged by the "finishing school" technique of balancing books on the head, or the military stance. Nothing could be further from the truth:

"The common admonition 'throw back your shoulders' is a poor and ineffective approach to good posture, while 'tuck in your stomach and throw out your chest' usually results in a tense, rigid, tiring posture which may be as bad as the posture it is intended to correct." (Howorth, 1946.)

The Alexander Technique assumes that most people indulge in "end-gaining", i.e. they work for short-term ends in terms of bodily function. In fact, there should be an inhibition of the immediate muscular response to a situation, so that there is adequate preparation for an activity.

Butenschön and Borchgrevink (1982, 7) emphasize that the head must be relaxed when singing, i.e. erect, with no restraint and not pulled down at the back. Furthermore, Negus (1929, 390), who is considered one of the greatest authorities on the larynx, says that singers should not have a backward tilting head position, a flat chest or drooping shoulders. These lead to abnormal strains upon the neck.
muscles which in turn cause chronic laryngeal tensions. Howorth (1946) believes that the head and chin should be level, not tilted back: there should be

"...a feeling of tallness, with the top of the head pulling away from the feet."

As Barlow (1973, 78) says, there are important nerves and blood vessels in the neck region which affect breathing, heart rate and blood pressure. These functions must be affected by posture. The importance of the head position to singers was noticed long ago: the head and neck should not be elevated too much for this causes the voice to be hard and dry with

"...too much strain on the nerves and arteries."

(Jumilhac, 1673, quoted by Duey, 1951, 68.)

And again:

"As for myself, I always acted with my pupils like a dancing master. I used to call my pupils one by one in front of me and after having placed them in the right position, 'Son,' I would say 'Look, observe...raise your head...don't lean it forward...nor backwards...but straight and natural.' In that position your vocal organs remain released and flexible, because if you lean your head forwards it [the neck] will suddenly become tense; also if the head is leaned backwards."

(Mancini, 1774, 93.)

There is an even more basic point:

"...the body should be kept erect, the head rather elevated, and the throat on a line with the body, that
there may be no angle or curve in the windpipe to prevent the free entrance and exit of the air."

(Lanza, 1813.)

Many other early writers on singing also emphasized the need for a correct head and neck position.

Alexander advised the use of a mirror so that one could observe one's own posture. (Singers are often advised to use a mirror to guard against awkward positions and expressions. Tosi, 1723, 88, advocated this method, for example.) Barlow (1973, 100) has pointed out that when angry we clench our hands, when afraid we hunch our shoulders, fix our chests and fidget. There are many singers who clench their fists or constantly move their fingers: these are widespread phenomena amongst the inexperienced. Further, Barlow says:

"I see a good number of people who have had a coronary thrombosis. I have never yet seen a case in which the upper chest was not markedly raised and over-contracted." (1973, 90.)

Dart (1947, 76) links poor posture to postural emphysema and cardio-respiratory failure, and he points out that profound postural change usually leads to difficulties in breathing; this is due to the fixed respiratory habits which people acquire: No wonder that operatic schools devote much time to teaching singers to breathe and sing in all the awkward positions which may occur during stage-work. Barlow (1973, 28) says that faulty patterns of breathing throw the muscles of the lower neck and upper ribs into excessive spasm.
Further, speaking of asthmatics:

"...recent studies show that after a course of breathing exercises', the majority of people breathe less efficiently than they did before they started them." (Barlow, 1973, 89.)

He links this with the paucity of information about wrong breathing habits, and makes the added point that there is a high correlation between personality disorder and misuse of the body which leads to conditions like chronic bronchitis and asthma. (Barlow, 1973, 89.)

It is appropriate to mention at this point that I am investigating the use of singing techniques in the treatment of people with respiratory problems.

B2: CORRECTION OF FAULTY POSTURE

The idea of lengthening is important, and Alexander Technique emphasizes this. Barlow (1973, 107) says that the key instructions one should give oneself are:

"Head - forward - and - up, back - lengthen - and - widen."

This is an ideal situation for correct breathing. A stance should be adopted with the knees slightly flexed, and the sexual organs pointed forward by forward tipping of the pelvis. (Barlow, 1973, 36.) This is described as dynamic posture by Howorth (1946):

"A slight crouch, with the ankles, knees and hips flexed, the head and trunk inclined forward and the trunk slightly flexed, the arms relaxed and slightly
When first adopting such a stance, considerable discomfort is felt, as old muscular habits are difficult to lose. The muscles are learning to lengthen so that they achieve a better resting length, and tension is being replaced by additional work in previously under-developed muscle groups. (Barlow, 1973, 55 and 162.) There is good evidence that the lengthening of joints has a beneficial effect, and Dart (1947, 88) quotes evidence to show that lengthening causes gas bubbles to form in synovial joints which alter surface tension and improve mobility. Lengthening and stretching exercises formed an important element in classes for singers run by Nancy Evans and her husband Eric Crozier at the Britten-Pears School in 1977.

I will now describe two exercises which are good in postural terms and which many singers have found useful. Firstly, there is the deep squat, which most people cannot achieve without help. Barlow (1973, 50) mentions this, so too does Dart (1947, 88):

"...the capacity to adopt the squatting posture in comfortable equilibrium is an absolute prerequisite for the poised erect posture..."

I was taught the squat by an Alexander teacher, and some back pain which I had suffered for several days disappeared immediately after the first correct squat.

Another exercise is what Dart calls the infantile supine posture. As described here in Dart's own words, this is
practically identical to the principal exercise taught by Alexander teachers:

"...lie on a carpeted floor with the occiput resting comfortably on several books...the feet drawn as close to the buttocks as possible without muscular strain (knees in the air and slightly abducted, elbows on the floor, and the relaxed hands resting on the junction of the thorax and abdomen). Fifteen to twenty minutes' midday rest in this symmetrical posture induces a gradual and progressive relaxation or inhibition of the sacro-spinalis mass in particular, and of the extensor musculature in general, and a temporary release from their inevitable state of torsional strain in the erect posture." (Dart, 1947, 84.)

I was told by an Alexander teacher (Johnston, 1983) that when performing this exercise, the eyes must be opened, as otherwise, muscle tone is lost. She said that this is a reason why meditative techniques may be bad posturally.

Strangely, one does not find many precise references to posture written by singers. One notable comment is from the soprano, Emma Thursby, quoted by Cooke (1921, 274). She emphasizes the importance of bodily poise in concert work; her other comments are generally in keeping with my suggestions for a correct stance, and she particularly notes the need for an absence of "military rigidity".

Cooke (1921, 295) also quotes the well-known Delsarte exercise. (François Delsarte, 1811 - 1871, was a French tenor and teacher. He developed a system of bodily
expression of emotion when singing, which was popular in the U.S.A. at the end of the nineteenth century. He left no written description of "The Delsarte Method".)

"I. Stand on the balls of your feet, heels just touching the floor.

"II. Hold your arms at your side in a relaxed condition.

"III. Move your arms forward until they form an angle of 45 degrees with the body. Press the palms down until the chest is up comfortably.

"IV. Now let your arms drop back without letting your chest fall. Feel a sense of ease and freedom over the whole body. Breathe naturally and deeply."
APPENDIX C: THE ANATOMY AND PHYSIOLOGY OF THE RESPIRATORY SYSTEM

C1: THE MECHANISM OF BREATHING

The primary function of breathing is to oxygenate the blood; the use of air to promote sound production is a secondary function, but I shall not deal with blood oxygenation in this work.

The lungs are sealed in an airtight, but flexible "box", the thorax. Movements of the thorax and diaphragm alter the volumes of the lungs, causing differences between the air pressure inside and outside the lungs. Air then rushes in or out of the windpipe (trachea) so that the pressures are equalized.

There are many groups of muscles which contribute to thoracic movements, but their actions are not always clear (Warwick & Williams, 1973, 515). However, the intercostal muscles are of primary importance, although again, there are conflicting views about which act as elevators or depressors of the thorax (Warwick & Williams, 1973, 515). The three groups of intercostal muscles are shown in Fig. C1, and the intercostalis externi are generally believed to act as elevators of the ribcage. The intercostalis interni and intimi are thought to be depressors. The supposed actions of the intercostal muscles and the resulting changes in the thorax are shown in Fig. C2.
FIG. C1: THE INTERCOSTAL MUSCLES (Adapted from Warwick & Williams, 1973, 515)

Diagram showing the intercostal muscles with labels:
- Ribs (costae)
- Intercostalis intimus
- Intercostalis internus
- Intercostalis externus
FIG. C2: MOVEMENTS OF THE THORAX DURING BREATHING (Adapted from Kapit & Elson, 1977, plate 77)

INSPIRATION

Expiration

Because of the hinge action of the sternum, the front of the thorax moves outwards during inspiration, just as the bucket handle moves away from the bucket as it rises to the horizontal.
A useful concept put forward by Vennard (1968, 22) is that any intercostal muscle fibre can be considered as a link in a chain connecting the ribs with the spine: this shows how elevation and depression of the thorax is achieved. (The directions of the muscle fibres are shown in Fig. C2(A).)

The diaphragm is a complex structure and is the principal muscle of inspiration: it accounts for about 75% of the normal tidal flow. However, it should be noted that thoracic breathing is more marked in women than in men (probably as an adaptation for pregnancy), and in both sexes during deep inspiration. As the diaphragm descends, its central tendon "becomes a fixed point [against the resistance of the abdominal contents] for the action of the diaphragm, the effect of which is to elevate the lower ribs and through them to push forwards the body of the sternum and the upper ribs." (Warwick & Williams, 1973, 517-518.)

The diaphragm is dome-shaped at rest, and maintains this shape when it moves downwards. It can move down from between 1.5 to 10 cm. (See Fig. C3.)

The capacity of the thorax can be increased either independently by the ribs and diaphragm, or in combination, in the transverse (ribs), anteroposterior (ribs) and vertical (diaphragm) dimensions. The diaphragm cannot contribute actively to expiration, but:

"The muscles of the abdominal wall raise the intra-abdominal pressure, forcing the relaxing diaphragm upwards and drawing the lower ribs downwards"
and medially."

And further:

"...controlled relaxation of the diaphragm in the nice adjustment of expiration necessary to speech and singing." (Warwick & Williams, 1973, 519.)

Brodnitz (1953, 40) points out that the diaphragm is the only voluntary muscle without a sense of position.

Respiration is often stated to be largely passive, and due to the relaxation of muscles and elastic and inertial forces in the lungs and other thoracic tissues. (For example, see Cotes, 1968, and Warwick & Williams, 1973, 518.) However,
active muscular contraction assists expiration when it is above the normal tidal flow.

The following is a summary of the main events during breathing:

**INSPIRATION**

1) The ribs rise and the diaphragm falls.

2) The pressure falls in the pleural cavity and the lungs expand to fill the increased space.

3) The external air pressure is now greater than that in the lungs, and air rushes in.

**EXPIRATION**

1) The ribs fall and the diaphragm rises.

2) The pressure increases in the pleural cavity and the lungs collapse as the available space decreases.

3) The external air pressure is now lower than that in the lungs, and air rushes out.
### TABLE C1: UNITS OF PRESSURE

Several different units are in use today, and one is likely to come across all of the following in books on singing. This table shows how they are related to each other, but I use only mm Hg in the present work as this unit is familiar, and used in much medical work.

1 millimetre of mercury (mm Hg)

- $1.36 \text{ centimetres of water (cm H}_2\text{O)}$
- $133 \text{ Newtons per square metre, or Pascals (N/m}^2\text{ or Pa)}$
- $0.019 \, 336 \, 7 \text{ pounds per square inch (lb/in}^2\text{)}$
- $1.332 \, 894 \, 7 \text{ millibars (mb)}$

"Standard" atmospheric pressure

- $760 \text{ mm Hg}$
- $1,033.6 \text{ cm H}_2\text{O}$
- $101,080 \text{ N/m}^2\text{ or Pa}$
- $14.695 \, 892 \text{ lb/in}^2$
- $1,013 \text{ mb}$

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C2: METHODS USED TO STUDY BREATHING IN SINGERS.

The study of lung capacities and related measurements is now well-developed, with such instruments as the Vitalograph spirometer providing detailed information. I carried out many experiments on singers and non-singers with this machine, and my results and full discussions are given in White (1980), and in less detail in White (1982B).
A number of methods have been used to study breathing whilst singing, but most of them interfere with the singing process in some way, albeit small, which may therefore lead to erroneous results. I have already mentioned in sub-section 3.2.3 the use of a mask to measure breath flow, and another technique which should be mentioned involves the pneumoplethysmograph. Here the subject's body is encased, and expansions of the thorax can be measured. Proctor (1980) gives details of the use of this apparatus with singers.

A new technique which I consider to be of great potential importance has been developed at Brompton Hospital. (New Scientist, 1982.) Bars of light are projected onto the subject's body, and distorted by breathing movements. These are then photographed and analyzed by computer, providing much detailed information. As far as I am aware, this technique has been used only clinically, but I intend to pursue its possible use with singers.

C3: THE LARYNX

C3.1: The origins of the human voice

It is important to realize that sound production is a secondary function of the larynx. It is primarily a valve for preventing the entry of foreign objects into the lungs: the sensitive vocal folds respond to foreign objects and set in motion the cough reflex. (Negus, 1949, says that coughing depends upon the closure of the false folds, but Ardran, Kemp & Manén, 1953, 504, say that the whole of the larynx from the vocal folds upwards is closed momentarily.)
Brodnitz (1953, 42) suggests that the larynx first appeared in amphibians in order to prevent water entering the lungs. He also points out the well-known fact that closing the vocal folds (as an outlet valve) when lifting turns the chest into a rigid cage which provides a good framework for the arm muscles. This valvular action is also used in bowel movements (p 43).

A rather different idea is proposed by Negus (1929 and 1949), who suggests that the vocal folds stop air from flowing into the lungs when hanging by the arms and swinging. Thus they would be well-developed in brachiating animals, which Man's ancestors undoubtedly were. He further suggests that the outlet valve is provided by the false folds as opposed to the vocal folds, and Thorp & Nicholl (1899, 27) agreed. Ardran, Kemp & Manén (1953, 507) say that this idea has not been sustained. The idea of the false folds acting as a valve has been put forward by many authorities, notably Steed (1879-1880); Wyllie (in Browne & Behnke, 1890, 236); Myer (1891); Lunn (1900, 45); Broekhoven (1908) and Taylor (1908). However, these writers had varying ideas about the mechanisms involved.

Other fascinating ideas about the development of the larynx are proposed by Lindahl (1970).

There are interesting theories about the evolution of sound production itself. Darwin (1882) suggested that the primaevale use of the voice was as a means of sexual attraction. (Sound production certainly has this function in many animals.) Russell (1978, 15) comments upon the need for
good control of breathing in both speech and fire control. The control of fire is believed to have played an important part in human evolution; blowing is necessary for successful fire control, and Man alone can blow successfully. Russell also mentions the famous theory that Man's ancestors lived on tropical shores in the Pliocene period. Good breath control supposedly developed for diving, and so Man was preadapted for speech production, which presumably evolved later.

Great nervous development has been necessary for the production of speech, and:

"The basic function of the respiratory system remains, naturally, vital to mere existence; but its primitive phonational potentiality, leading finally to speech, in all its permutations, would seem to be a fundamental factor in the evolution of human intelligence." (Warwick & Williams, 1973, 1173.)

C3.2: The structure of the larynx

Sufficient detail is included for the purposes of the present work, but a much more detailed account of this enormously complicated organ may be found in Warwick & Williams (1973).

The larynx is essentially a "box" constructed from various cartilages. These are shown from three positions in Fig. C4. The joints between the cartilages are synovial, and the relative movements of the cartilages are important in determining the condition of the vocal cords, and hence the
FIG. C4: BASIC STRUCTURE OF THE LARYNX  (Adapted from Kapit & Elson, 1977, Plate 73)

Notes
Arytenoid means "ladle-shaped". (Vennard, 1968, 53.)
Cricoid means "signet-ring-shaped".
Hyoid means "U-like". (Nathan, 1836, 119.)
Thyroid means "shield-like", and does not refer to the proximity of the thyroid gland.

Authorities vary about whether the hyoid should be treated as part of the larynx in a functional sense. For example, Butenschön & Borchgrevink (1982, 50) say that it should; Kapit & Elson (1977, Plate 73) say that it should not. Luchsinger & Arnold (1965, chapter VIII) point out that the hyoid can be removed for surgical reasons; its absence is not noticed at all. However, Fields (1947, 125) suggests that it holds open the superior entrance to the larynx, just as the cricoid holds open the inferior entrance. Ardren & Kemp (1967) review these and related ideas.

Honda, in Bless & Abbs (1985, 286-297), considers in detail the possible link which the hyoid provides between the movements of the tongue and movements of the larynx. Thus, he postulates, with good reason, that articulatory movements of the tongue affect pitch control by the larynx.
pitch of the voice. The cartilages are held together by ligaments and membranes.

The epiglottis assists during the action of swallowing, and its origin may lie in the complex functions which it performs in other animals, and which are not discussed here. However, Appelman (in Large, 1973, 82) says that the epiglottis assumes a specific position for each vowel, altering the orifice of the larynx (vestibular orifice). Ardran & Kemp (1967), in an interesting paper, discuss the functions of the epiglottis in great detail.

The thyroid, cricoid and arytenoid cartilages become gradually ossified, a process which may be completed by the age of 65 (Warwick & Williams, 1973, 1176), but which some claim is delayed by regular singing.

The position of the larynx in relation to its associated organs is shown in Fig. 6.3, but this diagram does not show the extrinsic laryngeal musculature which controls the position of the larynx. These external muscles are shown in detail in Fig. C5. They are of great significance in sound production, as they not only move the larynx (such movements are mentioned in section 5.3), but they tend to transmit laryngeal vibrations to other areas (Fields, 1947, 126), possibly affecting resonance, and certainly affecting proprioceptive feedback. Furthermore, Erickson, Baer & Harris (in Bless & Abbs, 1983, 279-285) discuss how these extrinsic muscles may contribute to the control of the fundamental frequency of the voice.
FIG. C5: THE EXTRINSIC LARYNGEAL MUSCULATURE
(Adapted from Proctor, 1980, 30)
The outer and inner muscle systems of the larynx have a common control by some branches of the nervous system (Butenschōn & Borchgrevink, 1982, 48). Thus it is a mistake to ignore completely the rôle of the external muscles in sound production, as some authorities do. I shall not attempt to describe the nervous innervation of the larynx in this work, but it should be pointed out that the units of nervous innervation are small: perhaps 30 muscle fibres to each motor neuron. Thus highly-skilled movements are possible (Warwick & Williams, 1973, 1183).

A superior view of the larynx is shown in Fig. C6, and the internal structure in Fig. C7. There are two pairs of vocal folds in the larynx: the false folds and the true vocal folds; the actions of the true vocal folds are disputed hotly. Strictly speaking, the term true vocal folds applies to the vocalis muscle (part of the thyro-arytenoid muscle) plus its elastic membrane, the connective tissue and the mucous membrane. The term true vocal cord applies only to the connective tissue margin of the fold, which is commonly called the vocal ligament (Butenschōn & Borchgrevink, 1982, 4). The fibres of the vocalis muscle are not attached to this (Warwick & Williams, 1973, 1180). In practice, it is often difficult to decide whether a writer is referring to the vocal folds or the vocal cords, and the terms tend to be used synonymously. I have generally used the term vocal folds throughout this work, unless quoting other authors, or where I refer specifically to the vocal cords.
FIG. C6: SUPERIOR ASPECT OF THE LARYNX (Adapted from Sundberg, 1977, 83)

Thyroid cartilage

Vocal Fold

Arytenoid cartilage

FIG. C7: THE INTERIOR OF THE LARYNX, SEEN FROM BEHIND
(Adapted from Butenschön & Borchgrevink, 1982, 51)

Epiglottis

False vocal fold (vestibular fold)

Vocal ligament (vocal cord)

Ventricle (sinus Morgagni)

True vocal fold

Thyro-arytenoid muscle

Elastic membrane (conus elasticus)

Cróicoïd cartilage
The internal muscles of the larynx are mostly named according to the cartilages to which they are attached. These muscles are not shown in detail in the accompanying diagrams, but some of their actions are inferred in Fig. C8, and explained in the notes which accompany that figure. It is worth noting at this point that singing involves the co-ordination of over 100 muscles. These include those of the abdomen, back, thorax, larynx and head. (Negus, 1929, 435, and others.) A detailed account of neuromuscular control during phonation is given by Wyke (in Bless & Abbs, 1983, 71-76). (See also sub-section 3.2.2.)
FIG. C8: THE ACTIONS OF SOME OF THE INTERNAL MUSCLES OF THE LARYNX
(Adapted from Warwick & Williams, 1973, 1181)

The arrows indicate the direction of pull of the muscles mentioned in each case.

A Abduction of vocal cords (Shown abducted by dotted lines.)
   Posterior cricoarytenoids *
   +

B Adduction of vocal cords (Shown adducted by dotted lines.)
   Lateral cricoarytenoids *

C Closure of rima glottidis, or glottis (Closure shown by dotted lines.)
   Transverse arytenoids *
   (Vocal cords and arytenoids are adducted, but the arytenoids are not rotated.)

D Tension of vocal cords
   Cricothyroids +
   (These muscles pull down the thyroid cartilage "like a visor". Butenschön & Borchgrevink, 1982, 49.)

E Relaxation of vocal cords
   Thyroarytenoids +
   The vocales, which are part of these muscles, may produce relaxation of the posterior parts of the vocal cords while the anterior parts are tense, and hence raise the pitch of the voice. (Warwick & Williams, 1973, 1181.) This is effectively a contribution to register changes: see Chapter 5.

* vary the glottis.
+ regulate tension of the vocal cords.

The laryngeal inlet is modified by the aryepiglottici and the thyroepiglottici.

The strength of the antagonistic muscles must be equalized, or there will be fluttering, breaks in the voice, etc. (Fields, 1947, 163 - 164.) Hence, perhaps, Lehmann's (1902, 40) great belief in the use of exercises to solve vocal problems and illnesses, rather than inactivity of the vocal organs.
The larynx is generally larger in men than in women, and it occupies a slightly lower position in men than in women and children.

**TABLE C2: AVERAGE DIMENSIONS OF THE LARYNX IN EUROPEAN ADULTS (Warwick & Williams, 1973, 1173 & 1179)**

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of larynx</td>
<td>44 mm</td>
<td>36 mm</td>
</tr>
<tr>
<td>Transverse diameter</td>
<td>43 mm</td>
<td>41 mm</td>
</tr>
<tr>
<td>Anteroposterior diameter</td>
<td>36 mm</td>
<td>26 mm</td>
</tr>
<tr>
<td>Length of rima glottidis/glottis (opening between the vocal cords)</td>
<td>23 mm</td>
<td>17 mm</td>
</tr>
</tbody>
</table>

Luchsinger & Arnold (1965) also give detailed dimensions of the vocal cords for different voices. They point out that in general, the cords of sopranos and tenors are short and broad, whilst those of contraltos and basses are long and narrow. The Adam's apple (front of the thyroid cartilage) is more prominent in men, particularly those with deep voices and correspondingly long vocal folds. As the pitch rises and the tension of the vocal folds increases, they may lengthen by up to 50%.

There is a sinus Morgagni between the vestibular (false) folds and the true vocal folds on each side; this leads up into a saccule. The latter contains many mucous glands,
whose secretions are squeezed onto the vocal folds. (See also section 5.4.) These saccules form air sacs in some apes, which contribute to sound production; but they apparently have no acoustical function in Man. (Husson & Dijan, 1952, quoted by Hardy, 1956, 145.) However, Lunn (1900, 150) says that singers should use the sinus Morgagni [and the saccules by implication] to increase the volume of the voice. How this is to be done is not clear.

C3.3: Observations of laryngeal movements

There are now many techniques available for studying the movements of the vocal organs, in addition to the laryngoscope. These include slow-motion cinematography; the use of stroboscopes (which can be very misleading, according to Weiss, 1959, 89); radiography (where the X-ray gun and photographic plate are stationary); and tomography (where the X-ray gun rotates, producing a clearer image than does radiography. (The cartilages do show up on radiographs, even if they are not ossified.) E.M.G. (electromyography) of the larynx muscles has shown that the head register differs from the chest and falsetto registers in degree and in kind. (Vennard & Hirano, in Large, 1973, 48.) Such techniques have allowed a better study of register mechanisms, but there is still doubt about many details.
APPENDIX D: VOICE TYPES

D1: INTRODUCTION

I have discussed the possibility of the inheritance of voice types in other works (White, 1980, 13-14, and White, 1982B, 143). No two voices are identical, but:

"Voice types illustrate continuous variation in the statistical sense, but can be divided into... categories...for practical purposes." (White, 1982B, 143.)

In other words, there is no clear dividing line between the soprano and mezzo-soprano voices, for example. This kind of distinction may be necessary if only to give composers some limits when writing vocal parts! Of course, some composers have tended to write outside the normally-accepted limits of a voice type: Purcell wrote some very low passages for countertenors; Verdi wrote some very high passages for baritones, leading to the evolution of the specialist "Verdi baritone".

Many singers are able to "change" voice types within reason when necessity demands: I appear as a "baritone" in Carmina Burana, for example, but as a "bass-baritone" or "bass" in Messiah or Bach's Passions. Regardless of terminology, a singer must simply ensure that he does not sing parts outside the comfortable limits of his voice, or ones which he is not capable of handling for some other, possibly artistic, reason. It is interesting in this connection to note the following comment by the medical writer, Brodnitz (1953, 76):
"Chaliapin was actually not a basso but a deep baritone and ran into considerable voice difficulties in his maturer years."

There is also the famous saying attributed to Rubini, when addressing Dupréz:

"You lost your voice because you always sang with your capital. I have kept mine because I have used only the interest." (Cooke, 1921, 218.)

Rubini may have been referring to over-singing generally, rather than to the excessive use of high notes, but the two features often go hand-in-hand and are equally detrimental.

As Luchsinger & Arnold (1965) have pointed out, the type of voice is decided partly by sound quality rather than range, and is dependent upon the dimensions of the larynx and supraglottic resonators, artistic inclination, cultural influences and the psychological personality structure.

There have been claims that individuals with a particular build tend to have a certain type of voice:

"There is much evidence to indicate that basses are often tall and athletic, whereas tenors usually have short, pyknic bodies. This was generally true of the subjects of this study, and in the author's experience this idea is borne out...in general. Baritones...tend to form a rather heterogeneous group as far as body type is concerned. No similar distinction appears to have been made for female singers; and none was apparent in the subjects studied." (White, 1980, 29.)
Perhaps the most extravagant claims in this respect were made by Weiss (quoted by Brodnitz, 1953, 78). He suggested that high voices were found in people with round faces, short noses, convex profiles with small delicate details, short necks, round or quadratic chests, high hard palates and delicate soft palates. On the other hand, deep voices were found in those with long faces, long noses, straight-line profiles with massive details, long narrow necks, large flat chests, broad hard palates and massive soft palates. Personal observation leads me to think that Weiss is generally correct, and it would be a relatively straightforward matter to survey a large group of singers and obtain statistical data.

High voices were always popular in earlier times; as evidence for this, Sadie (1980, 17, 339) quotes Chaucer's famous Prologue, lines 122-123:

"Ful weel she soong the service dyvyne,
Entuned in hir nose ful seme'ly."

The bass voice became more popular in the late fifteenth century, when there was an increase in musical "bass-consciousness".

D2: CASTRATI SINGERS

Although the castrato voice no longer exists, I shall deal with it briefly for the sake of completeness.

Exactly when and why castrati singers evolved is not known, but Proctor (1980, 5) suggests that they (and presumably other high male voices) arose because women were not allowed
to perform any functions in the Church.

Apparently, ancient actors carried out infibulation (tying of the genitals) in order to prevent sexual indulgence and thus preserve their voices. (Codronchi, 1597, quoted by Duey, 1951, 22.) Duey also suggests that castration would have been used for the same purpose, but as both practices might alter the voice (depending upon when they were carried out), I find it difficult to see the logic of this argument, unless they were carried out after puberty. However, they would then not have produced what we call castrati voices!

Eunuch singing was apparently the rule in the Eastern Church from the twelfth century onwards (Runciman, 1923, quoted by Duey, 1951, 48). Further, the last falsetto singer in the Sistine Chapel choir had died by 1625, because of the use of eunuchs. (Duey, 1951, 49.) (A useful paper by Milner, 1973, gives an interesting account of the use of castrati singers by the Church.) The last true castrato singer of all time was Alessandro Moreschi (1858-1922). He made a few recordings, but was by then past his prime, and they give a poor impression of the castrato voice.

The rise of Italian opera contributed to the great upsurge of castrati singers, (Hardwick & Hardwick, 1980, 84), and Sadie (1980, 17, 339) says that the female soprano was the only voice to rival the castrati in popularity. He also mentions that in the mid-sixteenth century, the instruction a voce mutata meant "without women's voices", and a voce piena meant "with women's voices".
It is estimated that in eighteenth-century Italy, up to 4,000 boys were castrated each year. (Häbock, 1927, quoted by Duey, 1951, 46. Häbock is the accepted authority on the castrato voice.) Castration has profound effects upon the body if it is carried out before puberty. Duey (1951, 52) gives an excellent account of these, and the main effects related to singing are as follows:

1) The body is larger than normal.
2) The chest becomes rounded.
3) There is very slow voice mutation; the young castrato has essentially the range of a woman or boy, with the breath control and power of a man.

de Bacilly (1668, 37) mentioned that puberty in boys occurred between the ages of 15 and 20. This is much later than is the case in general today. Häbock (1927, quoted by Duey, 1951, 168) mentions that researches in the nineteenth century showed that most of the soprani castrati were operated on between the ages of seven and 11, while the mezzi or contralti were operated on between 11 and 14. Both the soprano and contralto voices lowered with age, the soprano changing towards mezzo-soprano or contralto, and the contralto towards a high tenor.

Castrati allegedly had phenomenal breath control, due partly to their large bodily sizes and their small larynges, which were proved by dissection to be about 25% to 30% smaller than normal. (Duey, 1951, 168.) There is a marvellous account of Farinelli's breath control, written by Dr. Burney. (See Hardwick & Hardwick, 1980, 87.) Farinelli was the greatest of all the castrati; some have claimed that he
was the greatest singer who ever lived - he was certainly the eighteenth-century equivalent of Caruso in terms of fame. There was the ultimate accolade from a lady in his audience:

"One God, one Farinelli!" (Hardwick & Hardwick, 1980, 88-89.)

Burney (quoted by Hardwick & Hardwick, 1980, 88-89) praised him in unique fashion after he sang in England in 1734:

"He possessed such powers as never met before or since, in any one human being; powers that were irresistible, and which must subdue every hearer; the learned and the ignorant, the friend and the foe."

Finally, it is worth noting that Garcia (1894, vi) said that the castrati carried the art of singing "to its highest point of excellence".
APPENDIX E: ACOUSTICS

This Appendix provides some information which is additional to that in the main body of the thesis.
<table>
<thead>
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<th>Note</th>
<th>Frequency (Hz)</th>
<th>Note</th>
<th>Frequency (Hz)</th>
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<td>E4</td>
<td>329.63</td>
</tr>
<tr>
<td></td>
<td>77.782</td>
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<td>349.23</td>
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<tr>
<td>E2</td>
<td>82.407</td>
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<tr>
<td>F2</td>
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<td>G4</td>
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<tr>
<td></td>
<td>92.499</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G2</td>
<td>97.999</td>
<td>A4</td>
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<tr>
<td></td>
<td>103.83</td>
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<td></td>
</tr>
<tr>
<td>A2</td>
<td>110.00</td>
<td>B4</td>
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<tr>
<td></td>
<td>116.54</td>
<td>C5</td>
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<td>B2</td>
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<td>C3</td>
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<td>D5</td>
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<td></td>
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<tr>
<td>D3</td>
<td>146.83</td>
<td>E5</td>
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<td>698.46</td>
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<td>164.81</td>
<td>G5</td>
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<td>233.08</td>
<td>C6</td>
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<td>293.66</td>
<td>E6</td>
<td>1318.50</td>
</tr>
<tr>
<td></td>
<td>311.13</td>
<td></td>
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</tbody>
</table>

* Middle C. Horizontal lines separate octaves. (The octave notation is that recommended by the U.S.A. Standards Association).
El: VIBRATO

El.1: Introduction

"A good vibrato is a pulsation of pitch, usually accompanied with synchronous pulsations of loudness and timbre, of such extent and rate as to give a pleasing flexibility, tenderness, and richness to the tone." (Seashore, 1936, 7.)

There are four elements to consider, then: pitch, loudness, timbre and rate. A good vibrato is partly caused by an inability to exert a steady force of breath, and Wagner (1930, 207) makes it clear that good control by the diaphragm is essential. Seashore (1936, 7) considers this to be the most important of all musical ornaments, in voices and instruments, and the factor on which artistic singing and playing are most frequently judged, whether consciously recognized or not.

Vibrato is modified by illusions, and heard as very much smaller than it really is. A constant pulsation of 0.5 tone is usually heard as 0.2 tone or less, and may not be heard at all, even by musicians. (Seashore, 1936, 8 and 47.)

The vibrato may appear as soon as a child begins to sing naturally and with genuine feeling, and it is probably a physiological rhythm present whenever paired muscles are innervated under emotional tension. (Seashore, 1936, 55 and 139). Stanley and Maxfield (1933) quoted in Hardy (1956, 153) suggest that vibrato removes muscular fatigue, and is
the result of an "on/off" impulse which stimulates the entire muscular system controlling the tension of the vocal folds. Hardy (1956, 154) suggests that this fact means that vibrato should be absent on low intensities where the vocal folds are slack. He says that this was confirmed by Wolf et al (1935) and Potter et al (1947), the latter showing that in a note sung by Caruso, the vibrato disappeared with a diminuendo. However, Seashore (1936, 64) says that singers and listeners have the illusion that vibrato widens as a tone becomes louder.

"Great singers, teachers of voice, and voice students who are opposed to the vibrato and profess not to use it, do exhibit it in their best singing." (Seashore, 1936, 55.)

This statement has interesting implications for devotees of early music who often claim that they find vibrato an anathema, as emotional intensity will not be conveyed by musical sounds which lack vibrato: this may indeed be the intention.

Vennard (1968, 207) makes an interesting observation:

"There is the assertion that the music of Palestrina was to be sung in an echoing stone cathedral, and vibrato plus reverberation would be intolerable."

Vennard does not agree with this idea and cannot believe other evidence which purports to show that vibrato was not used in Renaissance music. Further, Miller (1977, 93)
implies that documentary evidence shows that Baroque music was not devoid of vibrato.

Sacerdote (1957, 66) found that vibrato tends to synchronize in choir voices. He points out that vibrato is an element of beauty in a choir, as in a single voice. Seashore (1936, 100) makes the important point that it is impossible to convey a beautiful vibrato to an audience, because what one hears another does not hear. He thinks that the ability to hear vibrato may be inherited. The listener's abilities and reactions are often overlooked. This is perhaps a suitable point at which to mention an interesting suggestion made by Taylor (1908, 158). He says that when listening to a "throaty" singer, the listener imitates the sounds mentally. Knowing that he would have to contract his own throat to produce such sounds, he feels uncomfortable:

"Every vocal tone awakens in the hearer a set of imagined muscular sensations." (p 160.)

(Taylor quotes other authorities on pp 167-168 in order to support his ideas, and a later writer who mentions the same theory is Plotkin, 1964.)

**El.2: Pitch vibrato**

Seashore (1936, 61) states that the typical pitch extent of vibrato of the best singers of the 1930's was 0.52 of a tone. This was about the same for men and women, which is particularly significant

"...when we consider that women sing an octave higher than men. It throws some light upon the effect of registers on pitch." (Seashore, 1936, 64.)
With regard to maintaining a correct pitch whilst singing, an interesting consideration is that a trained singer has learnt to do this whilst hearing pitches (from accompanying instruments) other than that being sung. (Hardy, 1956, 34.) A listener will interpret the mean pitch of the vibrato as the note being sung.

**E1.3: The rate of pitch vibrato**

Seashore (1936, 68) states that 6.5 Hz was the "probable average" for all singers investigated by various researchers. He says that a rate less than 5 Hz is intolerable; a rate greater than 8 Hz can be rarely maintained. (However, see section 6.6.) Seymour (1971, chap. 1) gives a range of 6-8 Hz for well-trained operatic singers, and a range of about 6-7 Hz has been mentioned by many workers. (For example, see Hardy, 1956, 160.) Seymour himself carried out a detailed analysis of pitch and intensity vibrato in a group of singers, using a very elaborate set of apparatus.

An important point made by Miller (1977, 95-96), and by other writers, is that a slower, wider vibrato is a result of ageing; it is probably due to reduced muscle tone and ossification in the larynx.

**E1.4: Intensity vibrato**

As the exact recording conditions are usually unknown, and because intensity is distorted in the cutting of discs, intensity vibrato cannot really be studied using gramophone
There would have been little point in trying to investigate this during the present study, but Seashore (1936) and Seymour (1971) do discuss this phenomenon in detail.

Intensity vibrato contributes to the overall impression of "beats" in a voice, which is experienced by the singer and heard by the listener. (See also section 6.3.)

Pitch and intensity vibrato are often out of phase in singers; by 180 degrees in some cases. (Hardy, 1956, 155.) In fact, Sacerdote (1957, 65) found that there is a phase difference of 180 degrees in professional singers, but none in non-professional voices. He found no other type of phase difference.

E1.5: Timbre vibrato
This is a periodic pulsation in the harmonic structure of a complex tone (Seashore, 1936, 80), and would have been completely hidden by the "maximizing" facility of the Brüel & Kjaer analyzer. However, whilst watching the monitor screen when recording a note, peaks could be seen building up, indicating that the harmonic structure was changing with time. (See Chapter 7 and section F7.)

E2: THE ACOUSTICAL PROPERTIES OF VIOLINS
I have found an interesting reference to the fact that some of the most musically-desirable violins show an increase in the amplitudes of the resonances in the range 2 KHz to 3 KHz. (Hutchins, 1981, 132.) I suggest that this might, like
the singing formant, help to carry the sound of a solo violin over the general sound of an orchestra. It should be noted, however, that a violin's high-pitched sounds should carry quite well even without such a feature.

E3: ARTIFICIAL MODELS OF THE LIVING VOCAL TRACT

Such models tend to fall into three categories:

1) The use of excised larynges.
2) The use of mechanical models.
3) The use of electrical analogues.

E3.1: Excised larynges

These have been used by many researchers, some of whom have reasoned that a dead larynx could be made to produce notes in the same way as a living one. This is clearly ridiculous, except in the broadest sense, as the living larynx must operate in a far more complex fashion than its dead counterpart. I shall not go into details regarding this matter, except to say that one must be cautious in accepting theories of voice production which are based mainly upon the examination of corpses. Browne & Behnke (1883, 115) said:

"...it is necessary to take great liberties with the dead larynx in order to produce tone...Experiments of this kind can therefore not be received as evidence except in so far as they are corroborated by investigations upon living persons."

Ferrein (see Ferrein, 1741) was the first person to demonstrate vocal cord vibration using excised larynges. This technique has been perfected by van den Berg. (Vennard, 1968, 210.) (See also notes on Müller, 1839, in section A5.)
E3.2: Mechanical models
Again, these may elucidate certain principles: the experiments of Cotton (1934) were mentioned in section 6.8. However, these models can tell us little about vocal fold vibration, for example, a topic discussed in section 4.3.

E3.3: Electrical analogues
These range in complexity from Fletcher's (1953) relatively simple design shown in Fig. El, to comparisons with electronic circuitry. (For a detailed example of the latter, see Seymour, 1971.) Electrical analogues have also been tackled by Dunn (1950), Stevens & Kasowski (1953) and van den Berg (1955) amongst others. Again, it is difficult to see what practical relevance such models might have for singers and singing teachers, although they present interesting academic exercises.
FIG. E1: AN ELECTRICAL ANALOGUE OF THE VOCAL TRACT  
(Adapted from Fletcher, 1953, 9)

RESONATORS
Tuned electrical networks (equivalent to the air chambers of the throat, mouth and nose)

VIBRATORS
a) Random
Constriction at mouth creates random noise

b) Periodic
Vocal folds (Equivalent to a buzzer)

POWER SUPPLY
Lungs equivalent to an electrical source

SOUND SPECTRUM

TYPE OF SOUND
a = unvoiced
b = mixed
c = voiced

PITCH
APPENDIX F: TECHNICAL MATTERS
RELATING TO THE ANALYSIS OF
RECORDED VOICES, AND DETAILS OF
THE EQUIPMENT USED

I dealt with some of the problems mentioned in this Appendix in a radio interview for the Canadian Broadcasting Corporation (White, 1984A.)

F1: PROBLEMS ASSOCIATED WITH THE STUDY OF GRAMOPHONE RECORDINGS
The quality of gramophone recordings is notoriously variable. Although it is possible to optimize the conditions for the replaying of almost any disc, one has no control over the recording and pressing processes.

F1.1: Recording Quality
The quality of the recording process has improved considerably since discs were first introduced by Emile Berliner in 1888. A landmark was the transition from acoustic to electrical recording in about 1925.

Two very variable factors are, of course, the quality and types of recording equipment used and the expertise of the recording engineers. Thus, even modern recordings may vary greatly in sound quality. Certain frequencies may be over-emphasized at the expense of others, and the recorded sound may be very different from the original. This would certainly be of importance in the present study, where the sound spectra of voices are investigated. (Hardy, 1956, 69, warned of this danger.)
Another problem concerns the relative balance of different voices and instruments in an ensemble, although this need not concern us here.

An interesting fact about acoustic recordings is that they apparently tended to have a response curve which peaked at between 2 KHz and 3 KHz. This coincides with the singing formant of male operatic singers, and would mean that any singer with a pronounced singing formant would have been a potentially good recording artist. (Pickett, 1982.) Caruso is said to have possessed the ideal voice qualities for acoustic recording, and descriptions of his voice and its power suggest that he would indeed have had a strong singing formant. On the other hand, acoustic recordings would have tended to have emphasized any singing formant which was present in a voice, thus distorting the sound spectrum!

The most serious defect in acoustic recordings is the resonant and reverberant qualities given to voices and instruments. These colouration characteristics vary from one recording to another. (Stockham, 1976.)

These facts demonstrates that one must exercise extreme caution when analyzing gramophone recordings, especially those of acoustic origin. (The singing formant is discussed in sub-section 6.7.6.)

All the transfers used in this study were on modern L.P. discs. "Original" 78 r.p.m. recordings are often transfers themselves, and the usually loud surface noise can play havoc with a sound spectrum analysis. In fact, even one loud
"click" can distort totally the spectrum displayed on a monitor.

It will be evident, then, that discs in a first-class condition are essential in this kind of work, and I used only pristine discs. All discs were washed, and treated with cleaning apparatus and anti-static fluid, as described by Watts (1969). A "Dust Bug" was used whilst a disc was playing, and all discs were "sprayed" with negative ions from an ionizer prior to playing. (A build-up of positive ions on a disc's surface causes the familiar static electrical noises.) I built the ionizer myself, and found that it markedly reduced the static problem. Fig. F1 shows technical details of the ionizer. (See also sub-section 3.2.7 for mention of the possible effects of air-borne ions upon health in general and the singing voice in particular.)
FIG. F1: CIRCUIT DIAGRAM OF THE IONIZER USED TO REMOVE STATIC ELECTRICITY FROM GRAMOPHONE RECORDS

Fuse

240 Volts 50 Hz

C2

D1 D2 D3 --etc. --

C1 C3

C26

D25 D26 D27

C27

R1

R2

R10

Sewing needle.

Fuse = 0.75 mA. C1 - C27 = 47 nF, 630 V. wkg. D1 - D27 = 1N4007, 1000 V. wkg. R1 - R10 = 3.3 m , 1/8 W.

This arrangement gives a discharge of negative ions from the needle at about 7.5 kV and 0.2 mA. This voltage avoids the over-production of ozone and nitrogen oxides, which would tend to build up at higher potentials.

Well-rounded blobs of solder are used in the circuit to prevent brush discharge, and the whole apparatus is encased in a completely insulated plastic box. The needle is situated in a plastic tube to prevent it being touched and causing electric shock.
Another factor beyond the control of an investigator is the quality of the pressing itself. It is well known that different batches of the same L.P. disc may vary enormously, and the gramophone industry is often criticized for this failing. I am confident that the discs used were of reasonable quality, but this is a subjective judgement.

F1.2: Problems of pitch

Although the modern concert pitch of $A = 440$ Hz was agreed internationally only in 1939, it seems reasonable to assume that most gramophone recordings would have been made at, or very near, this pitch. (For example, see Scholes, 1955, 814-815.) However, it has been suggested often that when some old recordings have been transferred to L.P. discs, the old discs have been played at the wrong speeds. 78 r.p.m. was not a universal speed for the old shellac discs, and might engineers have transferred, for example, 80 r.p.m. discs at 78 r.p.m.? Even if one has, as in the present study, several different transfers of the same recording, can one be sure that they have been transferred correctly? If they differ in pitch, which is correct?

This problem is probably of no great significance in the present work, but it will be seen that there are differences in pitch between different transfers. (See details of the recordings discussed in sub-section 8.4.12.) This may be misleading, because modern sound analysis equipment can sample sounds of a very short duration. Thus, despite great care, one may actually sample slightly different areas of the same note. Because few singers keep a sung note absolutely steady, and because of pitch vibrato, it may
appear that one is dealing with notes of different pitches. In fact, the overall pitch pattern may be the same. Moreover, the waveform and sound spectrum will change during the course of a note, and again, one cannot sample two transfers at identical points in order to obtain true comparisons.

The Brüel & Kjaer 3347 machine which was used to produce sound spectra has a "maximizing" facility which allows the display of the maximum RMS value measured during the time a button is depressed. This facility probably allows fairly accurate comparisons of spectra from different transfers. However, the Nova 4 computer produces a continuous waveform which is neither maximized nor averaged, and the operator has to select an area for print-out. It is unlikely that the same point in time will be chosen for two or more transfers of a particular recording, and slightly different waveforms might be expected.

F1.3: Vibrato

Seashore (1936, 25) states that phonograph records are entirely satisfactory for analyzing pitch vibrato, but not so useful for intensity vibrato and timbre vibrato. As Hardy (1956, 157) says, the intensity of the original sung tone is unknown. It is easy to see that the limitations of gramophone recordings which have been discussed already would tend to cause distortions. Pitch vibrato could be affected if the speed of rotation was incorrect or unsteady, or if the transferring process itself incorporated an error of speed, as mentioned above.
The vibrato elements of voices were not examined practically in any detail in this study, but these have been dealt with exhaustively in the past. For example, Seashore (1936) is a masterly exposition of the subject, and the apparatus which was available in the 1930's seems to have been adequate for the study of vibrato. There have been very detailed later studies, for example, by Seymour (1971). However, some interesting aspects of vibrato are discussed in sections 6.3, 6.4, 6.5, 6.6 and El.

F2: THE TRANSFER OF NOTES FOR ANALYSIS
In view of the difficulty of locating notes for analysis, and to avoid having to constantly handle gramophone discs, all notes were transferred to magnetic tape. I had found previously that this was an acceptable procedure, (White, 1980). Although a transfer from disc to tape must affect the quality of the recording, this was not felt to be significant, and there was really no alternative method which could be used in the circumstances.

F3: THE TRANSFER OF DISC RECORDINGS
These were transferred in the Music Studios of the University of Surrey, using the following equipment:

Turntable: Garrard 401 with stroboscope and adjustable speed control which was checked constantly for accuracy.

Arm assembly: Ortofon FF15E mk. II with elliptical diamond stylus.
Tape recorder: Studer professional studio model. Speed: 15 in./second. BASF professional tape was used, and stored with the leading end inwards, in order to minimize the problems of print-through. No equalization or Dolby noise reduction circuits were used.

There were two recording sessions (RR1 and RR2), and although the same equipment was used at each, I decided to check that there were no differences in conditions. I therefore duplicated the transfer of three notes, and compared their spectra and waveforms. There were differences, as described in sub-section 8.4.1, but these were not significant.

F4: THE RECORDINGS FOR THE CHEST RESONANCE EXPERIMENT
A Tandberg 15r-42 tape recorder was used, at a tape speed of 7.5 in/second. BASF professional tape was used, and a compatible microphone designed to give a fairly "flat" frequency response. I used this equipment for my M.Phil. research work, when it gave excellent results.

F5: THE PLAYING BACK OF RECORDINGS INTO THE NOVA 4 COMPUTER AND THE BRÜEL & KJAER 3347 ANALYZER
All tapes were played back using an Otari MX5050 tape recorder, which was of an extremely high quality. This machine was reasonably portable, and could be moved to where the other apparatus was situated.
PLATE F1: NOVA 4 COMPUTER

PLATE F2: BRÜEL & KJAER ANALYZER
F6: THE USE OF THE NOVA 4 COMPUTER

No details of this machine will be given here, but it was housed in the Department of Physics at the University of Surrey. (See Plate Fl.) A team headed by Dr. John Bowsher had produced software which could be used to analyze musical sounds, and I was allowed to use this. Four programs were relevant to the present study, and these are discussed below. Some of the details are taken from Bowsher (1980).

F6.1: D SPEC

This program will perform a pitch synchronous analysis on a waveform stored in integer format; the amplitudes of harmonics can be displayed in bar graph form, or in figures. This should allow a very detailed consideration of a sound spectrum, and the effects of vibrato would then be clearly seen. Unfortunately, the program could not handle operatic voices, and the Brüel & Kjaer 3347 Analyzer was used instead. The latter instrument provides a bar graph display, but in less detail than D SPEC.

It is necessary for D SPEC to "lock on" to a reference frequency, but the sound spectrum of an operatic voice is so complex that this is not possible. D SPEC has been used successfully with instrumental sounds and the voices of young children, but these are much less complex than a mature, trained, operatic voice. The practical analysis of vibrato was thus impossible with the available equipment, but as mentioned in sub-section F1.3, vibrato has been studied in detail in the past.
F6.2: Q RUN
This is a contiguous data file which can store a waveform in integer format. A sound of a duration of about 14 seconds can be stored, and this was more than enough time for each of the recorded sounds used in this study.

F6.3: S PLOT
This program displays the data recorded by Q RUN on an oscilloscope screen. A waveform is produced, i.e. a plot of amplitude against time, and the data are displayed in multiples of 4 blocks, as required. Each block represents a time period of 0.00512 seconds. The operator can select blocks from any part of the stored data, and thus choose which sections to print.

F6.4: B PLOT
This program causes the waveform to be printed. The operator has already decided which section to print by using S PLOT, and the B PLOT print-out is identical to the display seen on the oscilloscope. The vertical (i.e., amplitude) scale can be altered in order to avoid overloading the plotter, or merely to produce a waveform of suitable size.

As each block represents a specific amount of time, the exact frequency of a waveform can be calculated very accurately by measuring between repeated peaks. Thus I could check the pitch of a note; there is a proviso, however. As one is looking at a small part of a sound, the effects of vibrato cannot be seen, and one may obtain a false impression about the sung note as a whole. Care was exercised in order to avoid this error, as discussed in
section 7.2.

P7: THE USE OF THE BRÜEL & KJAER REAL-TIME THIRD OCTAVE ANALYZER TYPE 3347
(Some of this information is taken from Brüel & Kjaer, 1971.)

This machine is a combination of the Frequency Analyzer Type 2130 and the Control and Display Unit Type 4170. The display can be recorded automatically onto frequency-calibrated paper by means of the 2305 Level Recorder, and this instrument was used to produce the spectra shown in Chapters 7 and 8. (See Plate F2.)

The Analyzer contains 30 third octave filters of the audio frequency range (25 Hz to 20 KHz centre frequencies), which makes it less accurate than the Nicolet Mini-Ubiquitous Spectrum Analyzer Model 440A, which I used in my previous study. (White, 1980, 253.) Nevertheless, this is not necessarily a disadvantage in work of this kind, as very detailed information may be misleading, causing the investigator to attribute too much significance to his results. On the other hand, a small shift in frequency, as caused by frequency vibrato, could cause a "switch" from one filter to another, possibly causing confusion. Fig. F2 shows a typical spectrograph from the Nicolet instrument. This may be compared with the Brüel & Kjaer spectrographs in Chapters 7 and 8.
TABLE I: CENTRE FREQUENCIES OF THE 30 THIRD OCTAVE FILTERS OF THE BRÜEL & KJAER ANALYZER

<p>| | | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>25</td>
<td>250</td>
<td>2.5</td>
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<tr>
<td>31.5</td>
<td>315</td>
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<td>80</td>
<td>800</td>
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<td>100</td>
<td>1.0 KHz</td>
<td>10.0</td>
</tr>
<tr>
<td>125</td>
<td>1.25</td>
<td>12.5</td>
</tr>
<tr>
<td>160</td>
<td>1.6</td>
<td>16.0</td>
</tr>
<tr>
<td>200</td>
<td>2.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Sounds were entered into the analyzer whilst the "Max" storage mode was in operation. This display gives the maximum RMS value measured during the time the button is kept depressed. The "Store" button was pressed at an appropriate moment. Thus a good representation of the spectrum of the total duration was obtained. If unwanted "clicks" from a recording materially disturbed the display, the recording was not used.

No further details of the mode of operation will be given here, as the apparatus was used in the standard manner. However, I can provide full details of the exact settings used on each piece of equipment.
FIG. F2: SPECTROGRAPH OF GIGLI SINGING C#4; PRODUCED BY THE NICOLET MINI-UBIQUITOUS SPECTRUM ANALYZER, 440A
(Adapted from White, 1982D, 21.)

\[ F_1 \text{ Fundamental} = 425 \text{ Hz.} \]
APPENDIX G: SOURCES OF GRAMOPHONE RECORDINGS

The notes are listed in the order in which their waveforms and spectra are presented in Chapters 7 and 8.
<table>
<thead>
<tr>
<th>Reference number</th>
<th>Title of work and name of composer</th>
<th>Original matrix number of recording, if known</th>
<th>L.P. disc from which the note was tape-recorded</th>
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<td>RR2/74</td>
<td>As above</td>
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<td>As above</td>
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<td>RR2/100</td>
<td>As above</td>
<td></td>
<td>As above</td>
</tr>
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<td>RR2/11</td>
<td>&quot;Mi par d'udir&quot;. (Les Pécheurs de Perles: Bizet)</td>
<td></td>
<td>Boulevard 4072. (1972)</td>
</tr>
<tr>
<td>RR2/26</td>
<td>&quot;Ah si ben mio...&quot; (Il Trovatore: Verdi)</td>
<td>Victor 88121; C6034. (1908)</td>
<td>FID 2139. (1963)</td>
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<tr>
<td>RR2/27</td>
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<td>As above</td>
<td>As above</td>
</tr>
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<td>RR2/3</td>
<td>&quot;Miserere&quot;. (Il Trovatore: Verdi)</td>
<td>Victor 89030; C8506. (1910)</td>
<td>Boulevard 4072. (1972)</td>
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<td>As above</td>
<td>GVC 12. (1970)</td>
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<td>As above</td>
<td>As above</td>
<td>FID 2139. (1963)</td>
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<td>Ditto</td>
<td>Ditto</td>
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<tr>
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<td>&quot;Quest o quella&quot;. (Rigoletto: Verdi)</td>
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<td>B-6033-1. (16/3/1908)</td>
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<td>&quot;O Paradiso&quot;. (L'Africaine: Meyerbeer)</td>
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<td>&quot;Di quella pira&quot;. (II Trovatore: Verdi)</td>
<td>Victor 87001; B-3103-1. (11/2/1906)</td>
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<td>RR2/17</td>
<td>&quot;Esultate!&quot; (Otello: Verdi)</td>
<td>3001FT (DR100)</td>
<td>HLM 7026. (1973)</td>
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<td>RR2/22</td>
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<td>FID 2139. (1963)</td>
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<td>HLM 7026. (1973)</td>
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<td>Bb5034; DA645; (9/1924)</td>
<td>HLM 7004. (1972)</td>
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<td>&quot;Si, fui soldato&quot;. (Andrea Chenier: Giordano)</td>
<td>CM1168; DA1312. (3/1933)</td>
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<td>Reference number</td>
<td>Title of work and name of composer</td>
<td>Original matrix number of recording, if known</td>
<td>L.P. disc from which the note was tape-recorded</td>
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<td>RR2/40</td>
<td>&quot;Ach so fromm...&quot; (Martha: Flotow)</td>
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<td>RR1/3</td>
<td>&quot;Quando le sere al placido&quot; (Luisa Miller: Verdi)</td>
<td></td>
<td>SXL 6377</td>
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<tr>
<td>RR1/4</td>
<td>&quot;Dal più remoto esiglio&quot; (I Due Foscari: Verdi)</td>
<td></td>
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<td>RR1/5</td>
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<td>As above</td>
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<td>RR1/8</td>
<td>&quot;De este apacible rincon&quot; (Luisa Fernanda)</td>
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<td>RR1/9</td>
<td>&quot;Por el Lumo&quot; (Doña Francisquita)</td>
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<tr>
<td>RR1/10</td>
<td>&quot;Canto a la Espada&quot; (El Luésped del Sevillano)</td>
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<td>RR1/21</td>
<td>&quot;Dream Song&quot; (Manon: Massenet)</td>
<td>C.A.13007; DB961. (14/9/1932)</td>
<td>HLM 7004. (1972)</td>
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<td>RR1/22</td>
<td>&quot;O Paradiso&quot; (L'Africaine: Meyerbeer)</td>
<td>2SB573; DB3302/21621. (3/9/1937)</td>
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<td>RR1/23</td>
<td>&quot;Inutiles regrets&quot; (Les Troyens: Berlioz)</td>
<td>CLX1818/9; LX395. (11/12/1934)</td>
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<tr>
<td>RR1/31</td>
<td>&quot;Tu?! Indietro! Fuggi!&quot; (Otello: Verdi)</td>
<td>(1943)</td>
<td>Y31740</td>
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<tr>
<td>RR2/25</td>
<td>&quot;Il balen...&quot; (Il Trovatore: Verdi)</td>
<td>Fonotipia 92622; XPh3826. (1910)</td>
<td>FID 2139. (1963)</td>
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<td>RR1/32</td>
<td>&quot;Per me giunto&quot; (Don Carlos: Verdi)</td>
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<td>SUA 10617. (1964)</td>
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<td>&quot;Ego sum abbas&quot;. (Carmina Burana: Orff)</td>
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<td>&quot;Des troubles renaissants&quot;. (Les Huguenots: Meyerbeer)</td>
<td>Fonotipia 39027; XPh 512. (1904)</td>
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<td>&quot;Confutatis&quot;. (Requiem: Verdi)</td>
<td>(7/5/1929)</td>
<td>VIC 1470</td>
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<td>RR1/27</td>
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<td>&quot;Dormiro sol...&quot; (Don Carlos: Verdi)</td>
<td>(17/2/1927)</td>
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<td>C26102. (1920 - 1924)</td>
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<td>&quot;The Wind and the Rain&quot;. (Anon.)</td>
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<td>Oryx 1526</td>
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<td>RR1/11</td>
<td>&quot;Ah fors e lui...&quot; (La Traviata: Verdi)</td>
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<td>RCB 21</td>
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<td>RR1/24</td>
<td>&quot;Je veux vivre&quot;. (Romeo et Juliet: Gounod)</td>
<td>404c; DB367. (1905)</td>
<td>HLM 7026. (1973)</td>
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<td>RR1/18</td>
<td>&quot;Una voce poco fa&quot;. (Il Barbiere di Siviglia: Rossini)</td>
<td>DB830</td>
<td>Disc provided with Husler &amp; Rodd-Marling (1970)</td>
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<td>RR1/34</td>
<td>&quot;La luce langue&quot;. (Macbeth: Verdi)</td>
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<td>SXCP 30166. (1959)</td>
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APPENDIX H: BRIEF DETAILS OF THE SINGERS MENTIONED IN THIS WORK

Every singer who is mentioned in the main body of the thesis is listed below. This may seem exhaustive and unnecessary, but I have been conscious of the fact that many singers may be unfamiliar to some readers. A singer's dates help to place him in historical perspective, and the brief notes are intended to pinpoint the essential facts which are relevant to the present work.

Singers designated thus: * are those whose recordings were analyzed during this study.

All direct quotations, unless stated otherwise, are taken from Kutsch & Riemans (1969). Other comments are my own.

(Where notes accompanying gramophone records are quoted, I have simply given the reference numbers of the records; authors of such notes cannot always be identified.)

Abell (Abel), John. (1673 - 1717 or later.) Countertenor. A Scottish singer, composer and lutenist. There are many contemporary comments about his fine voice.


"... flexible and radiant tenor voice, whose expressiveness was supported by a mastery of singing technique."
He did not have the "baritonal" quality of Caruso, but:
"...absolutely faultless technique, superb evenness of tone and amazing breath control." (Notes with HLM 7038.)

*Callas, Maria. (1923 - 1977.) Soprano.
A dramatic soprano who was a fine actress. Her intonation was often inaccurate. She seemed to have distinct chest, middle and head registers. "She has three voices" was a common criticism (Rosenthal, 1966.)

"...most brilliant coloratura technique with physical strength and glowingly dramatic diction."

Cappuccilli, Piero. (b 1929.) Baritone.
One of the foremost baritones in the world. He has made many important recordings of Verdi's works, and is essentially a "Verdi baritone".

Carestini, Giovanni. (1705 - 1760.) Castrato alto.
He sang as a soprano at first and had a wide vocal range. He created many of Handel's roles, was much travelled, and Burney enthused over his voice:
"...whoever had not heard Carestini was unacquainted with the most perfect style of singing."

*Caruso, Enrico. (1873 - 1921.) Tenor.
"...originally a lyric tenor, but capable of the most dramatic climaxes. His phenomenal tone production, the smoothness of his registers, the nobility of his ...
singing style are even today to be marveled at in his more than two hundred records."

*Chaliapin, Feodor. (1873 - 1938.) Bass.

"... esteemed, next to Enrico Caruso, as the greatest artist of his time... He was a typical Russian bass in the elementary strength of his expressiveness and the tonal volume of his voice."

Probably the greatest singing actor of his generation, but not really what would have been called a bel canto singer.

Cuénod, Hughes. (b 1902.) Tenor.
A concert and operatic singer, and a great interpreter of Bach's music.

*dal Monte, Toti. (1898 - 1975.) Soprano.

"The floating lightness of her tone production and the exactitude and brilliance of her intonation in the most difficult coloratura passages made [her] one of the most noted coloraturas of the century."

"Her voice was small, pure, and inclined to whiteness. Its agility was remarkable." (Rosenthal & Warrack, 1979.)

de Gorgoza, Emilio. (1874 - 1949.) Baritone.

He was the husband of the soprano Emma Eames, and a noted boy soprano in England. He possessed one of the most beautiful baritone voices of his day. Although a concert singer and well-known recording artist in America, he never
appeared on the operatic stage.

*de Lucia, Fernando. (1860 - 1925.) Tenor.
"The exquisite musical beauty of his voice and his stylistic control of execution made him one of the most famous Italian tenors of the generation before Enrico Caruso."

"... a ringing, sonorous voice ..." (Notes with HLM 7026.)

de Reszke, Jean. (1850 - 1925.) Tenor.
A Polish singer of great refinement. He started to sing as a baritone and was later one of the leading tenors in the world. He was also famous as a teacher.

Deller was the first male alto or countertenor to make a mark on the musical world for two centuries. Michael Tippett said:

"... I heard Alfred Deller sing Purcell's Music for a While. It was not a very good arrangement of it; but for me, in that moment the centuries rolled back."
(Hardwick & Hardwick, 1980, 74.)

I was astonished when I heard Deller sing this piece on 20th June, 1979, at the last concert before his death; I have never heard his finesse, control, or beauty of sound excelled by any other singer of any voice type. My companion, an expert on Italian opera, said: "We shall never hear anything like that again". In my opinion, Deller's was
the most beautiful of all male falsetto voices and quite unique.

(See section 5.5 for more information on countertenors in general.)

*Delmas, Jean-François. (1861 - 1933.) Basso cantate/bass-baritone.

"A voluminous bass voice, whose wide range permitted him to undertake heroic baritone parts also."

"His singing is a model of musical declamation ... the nobility of his style ... In the opinion of the Wagner family he is the most perfect Wotan ever heard."

(Eaglefield-Hull, 1924.)

* Domingo, Placido. (b 1941.) Tenor.
Made his débût as a baritone in 1957, with his first major rôle as a tenor only three years later.

"The leading lyric-dramatic tenor since the death of Björling." (Rosenthal & Warrack, 1979.)

He has a dark, velvety voice, and sings a wide range of rôles, from those of Donizetti to Verdi's Otello.

Also a composer, he displayed outstanding phrasing, and was France's first true Romantic tenor. He was supposedly the first to sing top C (C5) in the chest voice (as opposed to falsetto) in Guillaume Tell. His voice declined early.
Farinelli (Carlo Broschi.) (1705 - 1782.) Castrato soprano. See section D2.

*Fischer-Dieskau, Dietrich. (b 1925.) Baritone.

"... warm and expressive baritone voice ... generally conceded to be one of the most renowned lieder singers of his time."

A very flexible voice. For example, he does not appear to be using the falsetto register in Orff’s Carmina Burana (SLPM 139 362), when other baritones would have to. An extremely versatile singer with an enormous repertoire of Lieder, oratorios and operas.

Garcia, Manuel, the elder (del Popolo Vicente Rodriguez Garcia). (1775 - 1832.) Tenor. See section A4 and Fig. A2.

Garcia, Manuel, the younger. (1805 - 1906.) Baritone. See sections A5, A6 and Fig. A2.

*Gigli, Beniamino. (1890-1957.) Tenor.

"After the death of Enrico Caruso he was generally held to be the most famous tenor of his generation ... The splendor of his voice, the colorful shading of his singing, the minute voice control, especially in mezza di voce singing, remain vividly alive on his many phonograph recordings."
Gostling held many church positions: he was, for example, a 
minor canon of Canterbury and St. Paul's, a canon of Lincoln 
and a Gentleman of the Chapel Royal. He was a noted copyist 
of music and had an outstanding deep bass voice. (See 
sub-section 5.5.3 for a comment on his voice.)

*Harwood, Elizabeth. (b 1938.) Soprano.  
A pupil of Lucie Manén when these recordings were made. She 
is especially successful in Mozart's music, and has an 
international reputation.

Hempel, Frieda. (1885 - 1955.) Soprano.  
A coloratura singer with a wide Italian repertoire, 
especially famous in Mozart's works. She was best-known for 
her portrayal of the Queen of the Night. She later gave 
"Jenny Lind" recitals in period costume.

*Hemsley, Thomas. (b 1927.) Baritone.  
A pupil of Lucie Manén when these recordings were made. A 
very experienced baritone with international experience, and 
a fine singer of Lieder. I studied with Hemsley at the 
Britten-Pears School for Advanced Musical Studies in 1977 

Hughes (Hughes), Francis. (1666/1667 -1744.) Countertenor.  
A singer with a strong voice, but probably ousted from opera 
by the castrati.
Lablache, Luigi. (1794 - 1858.) Bass.
A great singer and actor, and the leading bass of his generation. His voice was deep and powerful, and he was an imposing figure. He was Princess (later Queen) Victoria's singing master in 1836 - 1837.

"...greatest of all basses...if the accounts of his contemporaries are correct, we have never beheld his equal." (Henderson, 1938.)


"Her singing career is one of the longest known. Even at the age of seventy she was still appearing ... One of the most important figures in the history of singing, she was unsurpassed in the universality of her vocal endowments and in the deep artistic seriousness with which she dedicated herself to each performance."

"The greatest Wagnerian soprano of the last century." (Cooke, 1921.)

"The greatest dramatic soprano of our time." (Henderson, 1938.)

Lind (Lind-Goldschmidt), Jenny. (1820 - 1887.) Soprano.
Known as "The Swedish Nightingale", she had an outstanding voice, and was mainly a recitalist and oratorio singer. She was professor of singing at the Royal College of Music in London from 1883.
Malibran (Garcia), Maria Felicia. (1808 - 1836.) Contralto.
One of the greatest operatic contraltos of the nineteenth century. Sister of Manuel Garcia the younger. (See Fig. A2.)

Marchesi, Luigi. (1754 - 1829.) Castrato soprano.
"He excelled in passages of extreme virtuosity, and was quite vain and arrogant, both because of his vocal prowess and his effect on other men's wives." (Bacon, 1824, 132.)

With Gigli, one of the most famous tenors of his day. His voice was not unusually powerful, but he had remarkable breath-control.

"His voice was of exquisite tonal quality, equally polished in technical characteristics and in stylistic subtlety."

He made 561 known published gramophone records and cylinders. (Notes with CDM 1057.)

"Even then [in 1926] her voice retained the fresh youthfulness of timbre which had marked it at the outset of her career ... She had a legendary soprano voice of great beauty and a silvery timbre. Her coloratura roles were admirable for her technical mastery, and in lyric parts her voice was admired for its splendid tonal quality."

"... esteemed to be uncontestedly the greatest Wagner tenor of his time...[his voice had] the ideal qualities of the heroic tenor: its baritone warmth, its brilliance in dramatic conception."

He made his début in 1913 as a baritone, but sang tenor rôles after 1918.


He had a long and successful career at Covent Garden and was a famous oratorio tenor.

"Arguably Britain's finest tenor ... dubbed the 'English Bjorling'... the effortless quality of his singing ... the lightness of his timbre." (Notes with HLM 7004.)

Oberlin, Russell. (b 1928.) Countertenor.

Also a well-known teacher, and a leading exponent of early music. He has a beautiful tone and was Oberon in the first Covent Garden production of Britten's A Midsummer Night's Dream in 1961

*Pavarotti, Luciano. (b 1935.) Tenor.

"Specializes in bel canto repertory; has a fine technique and a voice of considerable beauty."

(Rosenthal & Warrack, 1979.)

One of the world's leading tenors, but essentially a lyrical singer.
Pears, Sir Peter. (b 1910). Tenor.
An intelligent singer with great musicianship. His vocal expression is remarkable, but the timbre of his voice is not immediately attractive to many, as it is penetrating and reedy. He was an outstanding Evangelist and Gerontius, and much of Britten's music was composed for him. At one time a pupil of Lucie Manó, they apparently parted on unfriendly terms.

"A warm-timbred and very flexible bass voice with great affective powers."

"[During the inter-war years, he was] ... the supreme exemplar of the Italian school of bass singing and reigned as undisputed basso cantate supremo." (Notes with VIC 1470.)

Purcell, Henry. (1658/1659 - 1695.) Countertenor.
See sub-sections 5.5.1, 5.5.2 and 5.5.3 for comments on his voice.

Rubini, Giovanni Battista. (1794 - 1854.) Tenor.
A great tenor, with a ravishing voice and a phenomenally high falsetto range, but he had a comparatively short career. He influenced Donnizetti, and created many rôles in his operas.

"As a singer and nothing but a singer he is the only man of his class who deserves to be named in these pages as an artist of genius." (Chorley, 1862.)
*Schipa, Tito. (1889 - 1965.) Tenor.

"The voice ... was the ideal of the bel canto lyric tenor; its velvety melodic line, the fine shadings of characterizations, and the effortlessness of his singing ... even at the age of seventy he still gave concerts."

Schipa's amazing control of dynamics is shown clearly in a sound analysis described by Sacerdote (1957, 62). Gigli said:

"When Schipa sang we all had to bow down to his greatness." (Notes with HLM 7004.)

Senesino (Francesco Bernardi). (c 1680 - 1759.) Castrato alto.

His nickname derived from his birthplace, Sienna, and he achieved spectacular success as a singer. He was a master of coloratura and Handel composed many parts for him. He was arrogant and clashed with Handel, but very popular in London, where some held that he made a greater impression than Farinelli.

*Stracciari, Riccardo. (1875 - 1955.) Baritone.

" ... one of the most beautiful baritone voices which Italy produced in his generation; he was especially admired for the elegance of his parlando singing."

Sutherland, Dame Joan. (b 1926.) Soprano.

A coloratura singer who specializes in very florid music, particularly French and Italian operatic music of the
nineteenth century. She is the greatest Australian singer since Melba.

*Tamagno, Francesco. (1850 - 1905.) Tenor.

"Verdi admired his voice and called him 'unique in the whole world'."

He created the rôle of Otello at La Scala, Milan:

"In this role no successor has ever matched his performance."

"... the ideal [voice] of the heroic tenor. The basic weight of the voice, its driving dramatic force, and the brilliance in the upper registers are even on records, truly remarkable... severe heart attack in 1898 left a noticeable mark."

It is interesting that Tamagno's records were made after his heart attack, when he was past his best.


"... one of the most beautiful lyric tenor voices preserved on records. He was unmatched in the richness of nuance in his characterizations and in the ease of his tone production."

Considered to have been one of the greatest Mozart singers of his day. Elizabeth Schwarzkopf said:

"He was the greatest tenor I had the fortune to hear, or, for that matter, to sing with." (Notes with SRS 5065.)
Tetrazzini, Luisa. (1871 - 1940.) Soprano.
A coloratura singer of astonishing technical ability and virtuosity.

*Thill, Georges. (b 1897.) Tenor.
"The most celebrated French tenor of his epoch, he was noted for the expressiveness of his voice and for its brilliant timbre."

Thursby, Emma. (1845 - 1931.) Soprano.
A coloratura singer and a teacher.

Tinayre, Yves. (1891 - 1972.) Tenor.
A music scholar and singer (mainly a recitalist), with a fairly light voice.

Tosi, Pietro. (c 1653 - 1732.) Castrato.
A well-known singer and a famous teacher. (See comments in Chapter 2 and section A4.)

*Valdengo, Giuseppe. (b 1914.) Baritone.
Studied under Toscanini; a singer with a thorough mastery of vocal technique. A typical bel canto singer.

Viardot (Garcia or Viardot-Garcia), Michelle Pauline. (1821 - 1910.) Mezzo-soprano.
An outstanding singer with an extended range. Sister of Manuel Garcia the younger. (See Fig. A2.)
Zenatello, Giovanni. (1876 - 1949.) Tenor.

Made his début as a baritone in 1899, appearing as a tenor two years later.

"A magnificently handled and brilliant heroic tenor voice; one of the finest voices which Italy has produced in this century... He was considered the greatest interpreter [of Otello] after Francesco Tamagno."

APPENDIX J: SUMMARY OF RELEVANT RESULTS AND CONCLUSIONS FROM M. PHIL. THESIS

(All page numbers in this section refer to White, 1980, unless stated otherwise. Many of these points are also discussed in White, 1982B.)

J1: SKELETAL FACTORS

1) As expected, significant differences were found between the skull measurements and shapes of males and females (p 80) and vocal range appeared to increase as skull size decreased (p 229). This could have been related to the sizes of head cavities.

2) It appeared likely that there was no relationship between external head measurements and the sizes of sinuses. No X-ray plates of famous singers could be traced which might have shown the sinuses. (p 23.) (I have discovered recently that transillumination might be a useful tool in studying the sinuses. Brodnitz, 1953, 140-141, describes how a small electric lamp placed in the mouth or under the eyebrows may illuminate the maxillary and frontal sinuses in a darkened room.)

3) There was no connection between the numbers of teeth and fillings, and the voice. (p 188.)
J2: LUNG FUNCTION

1) In general, there were interesting relationships between some lung parameters and diverse other anatomical and physiological factors.

2) FVC (Forced Vital Capacity) diaphragm expansion and phonation time were very variable, and there were no patterns related to males or females, singers or non-singers. (pp 186-189.)

3) It was reasoned that one might expect the FEV1 (Forced Expiratory Volume in one second) to be higher than normal in tenors because of their short builds. (Erratum to p 231.) This might aid the rapid expulsion of breath, and thus the production of high notes. Thus, not all singers might be expected to show the same performance in terms of lung function.

J3: VOCAL ACOUSTICS AND HEARING

1) It was not possible to confirm two theories put forward by other authors. Firstly, there was an attempt to relate sound qualities to measurable factors (Luchsinger & Arnold, 1965):

"Dark" timbre [i.e. "covered"]: low partials predominate.

"Light" timbre [i.e. "open"]: higher partials predominate.

"Dull" timbre: too few higher harmonics.
"Shrill" timbre: too many higher harmonics.

"Sharp" timbre: emphasis of the 3 KHz to 4 KHz range.

Secondly, there were ideas proposed by Pielke, that there is a weak second harmonic in "closed" ("covered") singing, and a prominent second harmonic in "open" singing. Further, he suggested that there is a strong fundamental and rich harmonics in "covered" singing. (Pielke, 1910, quoted in Luchsinger & Arnold, 1965, chapter 6.)

In fact, my data seemed remarkable for their lack of correlation in all these respects. (p 149.) (This could have been due to the relatively small sample size involved, or to my subjective opinions of voice qualities.)

2) The fundamental was commonly the strongest harmonic in females, but not in males. (p 150.)

3) Males showed a higher number of harmonic components than females. It was suggested that this was because the male fundamentals were of lower pitch, and therefore there were more harmonics in the range analyzed. (p 156.) Seymour (1971) also noticed this, and the fact that females do not tend to show higher maximum partials than males when singing similar notes. (It should be mentioned that Colton, 1972, 341 and 343, states that in the modal register, the number of partials decreases as the fundamental rises. Thus observers experience great difficulty in judging whether sounds are falsetto or modal at high pitches.)
4) There were no striking differences between the numbers of partials produced by singers and non-singers. (p 156.)

5) Seymour (1971), quoted on p 123, showed that at the 1% level of significance, the number of non-harmonic components in male voices increased steadily in the order:
   
   "technical" notes: trained singers during vocal exercises.

   "performed" notes: trained singers during performances of songs.

   "mature" notes: international artists.

6) I found that Caruso and Gigli showed a high number of harmonic and inharmonic components when compared with most of the subjects of the study. (p 123.)

7) Male subjects tended to modify the first formant area of "ah" more than females, and non-singers more than singers. (This latter case could have been due to poor singing technique.) (p 150.)

8) Males produced the high singing formant more often than females, and singers more often than non-singers. (p 153.)
"It did not appear possible to lay down specific criteria likely to be observed in the sound spectrographs of good voices, apart from the appearance of the singing formant."