Understanding the operatic tenor's legitimate head voice: A comparative study of historical and modern pedagogical approaches

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ABSTRACT

The modern operatic tenor, with his chest-voice-like upper register, produces a vastly different sound to that of the castrato-trained *tenore di grazia* of the eighteenth century. Notwithstanding this change in tenor vocality, the practice of register-blending or -unification, originally developed by the castrati as a means of extending their voices upwards with a seamless transition to the falsetto register, has remained a core element of classical voice training. The change in tenor vocality did, however, provide an impetus for the evolution of this pedagogical practice during the nineteenth century. It led to the emergence of "mixed voice" as the purported mechanism for the tenor's upper register, and the introduction of a more mechanistic approach to register-blending or -unification as a means of developing the mixed voice source mechanism. In light of more recent discoveries in voice science, the validity of the register-blending or -unification approach has been called into question. An important, albeit minority, view is that the tenor's legitimate head voice is simply an upwards extension of his chest voice mechanism. Science has not found any evidence of a "mixed voice" laryngeal mechanism, while there is evidence suggesting that it is possible to extend the chest voice mechanism upwards through vocal training that strengthens the thyroarytenoid muscle, coupled with the development of the necessary fine motor skill to maintain balanced adduction of the top and bottom edges of the vocal folds at high pitches. If this view is correct, it would have important implications for tenor training methods, in particular the practice of register-blending or -unification in the mechanistic sense.

ACKNOWLEDGEMENTS

I wish to express my sincerest gratitude to my supervisors, Prof. Hendrik Hofmeyr and Dr Martin Vanlierde, who have been more generous with their time, effort, support and meticulous attention to detail than I could have expected; to Katherine Bleazard for much patience and forbearance, unerring detection of verbiage and being an infallible touchstone for the flow of the argument; to Colleen Radus for the generous barter arrangement for her professional proofreading and editing services; to Dr Barry Smith for his generous proof-reading contribution; to accomplished countertenor, friend and colleague, Christopher Ainslie, for joining me in an endolaryngoscopic torture session; and last, but not least, to Shaheema Luckan and Jaimee Cloete for their tireless efforts in chasing down countless obscure journal references and for never questioning my perpetual renewals of library loans.

To the memory of George Stevens, singer extraordinaire,
friend, mentor, and inspiration to all whose lives he touched;
taken from us far too soon…

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1. INTRODUCTION

1.1. The modern tenor and the voice register problem

Operatic tenors are among the most admired of Western classical musicians, and none more so than those who are able to thrill audiences with robust and ringing high notes. The excitement of these so-called "money notes" is especially heightened when the power and tonal quality of the singer's upper register matches that of his lower register, or so-called chest voice.

An historical overview of Western classical vocal technique reveals that tenors did not always possess this chest-voice-like upper register, which is variously referred to as the legitimate head voice,[1] full head voice, or *voce piena di testa*. This potential in the tenor voice was only discovered in the first half of the nineteenth century, which is surprising if one considers that the act of singing is probably as old as mankind itself, and that singing has been practised as a profession by gifted individuals for much of recorded history (Potter and Sorrell 2012, 40-43). Furthermore, anthropologists agree that mankind's vocal apparatus has essentially remained unchanged since the advent of language (Potter 2009, 2, 192). It follows, therefore, that the phenomenon of the modern tenor is the product, not of any recent evolutionary changes to the phonatory organ, but of a relatively recent evolution in vocal technique.

The driving force behind the evolution of Western classical vocal technique was the continuous pushing of boundaries in terms of expanding vocal ranges and a need for increased projection to fill larger venues over louder accompaniment (Potter 2007, 97). As singers strived to extend their vocal ranges, they inevitably encountered difficulties with a register break around the middle of the voice. This is where the low register normally used for speech, commonly referred to as chest voice, gives way to falsetto, the flute-like upper register which is somewhat reminiscent of a pre-pubescent treble voice. The difficulty is most visible in untrained male singers as they are generally only able to extend their chest voices up to G4,[2] at which point it is likely to resemble a yell. The great effort required to phonate at

[1] The term, "legitimate head voice", which was coined by Richard Miller (1986, 118), carries a value judgement insofar as it implies the existence of other "less legitimate" strategies that a tenor may use to produce his high notes. The latter includes reliance on the falsetto register, literally meaning "little false voice", which similarly implies a value judgement.

[2] Scientific pitch notation (SPN) is used to identify pitches in this dissertation. According to this system, octaves are numbered with reference to C, the lowest C on the piano being C1. Notes below C1 are designated with 0, the lowest note on the piano being A0. Middle C (261.63 Hz), which represents the centre of the tenor voice, is C4. Thus, the lowest C that a typical tenor can reach is notated as C3 (130.81 Hz), while the famed tenor "high C" (523.25 Hz) corresponds to C5. It must be noted that the tenor is conventionally notated in the treble clef an octave higher than it sounds. There are other, arguably more logical, systems of pitch notation, but SPN is the *de facto* standard notation system used in all scientific writings in voice science, possibly because singers naturally think

these pitches is unsustainable for most individuals, and any attempt to sing higher is likely to cause an embarrassing vocal "crack", which marks an involuntary and uncontrolled frequency jump, with an attendant switch to falsetto at the point where the muscular strength of the chest voice mechanism fails (Frisell 1968, 17, Vennard 1968, 67).

The famed castrati of the seventeenth and eighteenth centuries presented the first solution to the register problem through a pioneering technique for achieving a smooth transition between chest voice and falsetto. Castrato-trained tenors would eventually benefit from this breakthrough in vocal technique, enabling them to evolve from the single-register singer of the Renaissance period (whose range was equivalent to that of the modern baritone) to the *tenore di grazia* ("graceful tenor") of the old bel canto school, who was able to reach exceptionally high notes (up to F5) using a falsetto-based technique for their upper register.

By the middle of the nineteenth century the influence of the castrati and their teaching methods was waning, leaving tenors free to explore new possibilities in their voices. We now see the emergence of the modern tenor, who developed an ability to sing the upper fifth of his range (F4 to C5, and in exceptional cases, even higher) with a vocal quality that is indistinguishable from chest voice. This vocal quality in the upper register is now characteristic of the modern tenor (Potter 1998, 56), and tenors who are unable to achieve the necessary skill to produce "chested" high notes generally find their career potential limited (R. Miller 1993, 130).

This change in tenor vocality has only served to exacerbate the tenor's register problem. While it is no longer acceptable for a tenor to use a falsetto-based technique in his upper register, any attempt to carry an unmodified chest voice above the register break at G4 will lead to complaints of register violation,[3] which is equally unacceptable in the modern operatic idiom (McCoy 2012, 155-156). This presents unique challenges for a tenor in the development of his upper register.

1.2. The research problem

The aim of the research documented in this dissertation is to gain a deeper understanding of the optimal development of the tenor's legitimate head voice by identifying potential solutions to the register problem that satisfy the vocal ideal of the modern tenor. To this end, I present a comparative analysis of historical and contemporary pedagogical approaches to the development of the upper extension of

in octaves that are centred on middle C. SPN is particularly convenient when discussing tenor voices, given that the typical usable vocal range of a tenor spans two octaves from C3 to C5.

[3] Register violation refers to the singing of a note in an inappropriate register. This would typically be a high note sung in a register appropriate for the lower part of the voice (D. G. Miller 2000, 44).

operatic voices, with specific reference to the tenor's upper register, followed by a discussion of these approaches in the light of modern voice science.

1.3. Literature review: the lost "Golden Age" or old-school methods for modern results

The pedagogical literature does not reflect a universal acceptance of the modern tenor sound, nor the changes in vocal technique which underpinned its emergence in the mid-nineteenth century (see 2.3 below). On the contrary, many influential pedagogical voices from the twentieth and twenty-first centuries lament a decline in the standard of contemporary classical singing and express a romantic hankering after the glories of the Old Italian School of Singing (Bloem-Hubatka 2012, 5-14, Herbert-Caesari 1936, xix-xx, Reid 1950, 155-157). Such authors assert the superiority of this old-school tradition, claiming that it represents a uniform and unbroken tradition of infallible vocal truth as documented in treatises published over the course of almost two centuries – from the first comprehensive treatise on singing by Pier Francesco Tosi in 1723 (see 3.2 below) to that of Giovanni Battista Lamperti in 1905 (3.3.6. below) (Bloem-Hubatka 2012, 13, Reid 1950, 155, 164, R. Miller 1986, xx-xxi, 89). Where these critics of modern singing technique do have words of praise for singers from the modern era, it is to exalt them as unquestionable exponents of the Old Italian School of Singing in its purest form (Bloem-Hubatka 2012, 99, Herbert-Caesari 1957, 116).[4]

It is perhaps due to this passionate advocacy for a revival of the lost "Golden Age of Singing" that the old-school methods, albeit in evolved form as I will show in Chapter 3, remain firmly entrenched in the pedagogical mainstream. This continued adherence to the old-school tradition is bolstered by the fact that singers from the modern era (albeit mostly dating from the early to mid-twentieth century) who are often held up as paragons of the Old Italian School of Singing, including tenors such as Jussi Björling, Ferruccio Tagliavini, Beniamino Gigli, John McCormack, and even Enrico Caruso (Bloem-Hubatka 2012, 99, Herbert-Caesari 1957, 116), indisputably epitomise the modern classical vocal ideal.

A key concept harking back to the origins of the venerated Old Italian School of Singing is that falsetto development and register-blending or unification is required to achieve an extended singing range with a uniform and balanced tone quality (Celetti 1991, 113, Vennard 1968, 73-79, Reid 1965, 52-70, Frisell

[4] Just about every authority on vocal pedagogy, from Tosi to Garcia, as well as composers from Caccini to Verdi, complained of a decline in the art of singing (Stark 1999, 216-225). The following statement by George Bernard Shaw, quoted by Stark (1999, 216), ridicules this time-honoured view:

> "The notion that singing has deteriorated in the present century is only a phase of the Good Old Times delusion [...] Every musical period suffers from the illusion that it has lost the art of singing, and looks back to an imaginary golden age in which all singers had the secret of the bel canto taught by Italian magicians and practiced in excelsis at the great Opera Houses of Europe."

1968, Jones 2017, 119). This practice, which has formed part of the foundation of Western classical vocal training since the early eighteenth century (D. G. Miller 2000, 31, Miller and Schutte 2005), holds intuitive appeal. Firstly, as Giles (1994, 4, 6) points out, the use of falsetto has ancient origins and remains instinctive even in modern times. Secondly, it embraces the empirical existence of the chest and falsetto registers, while also accounting for the difficulties that most untrained male voices have when attempting to phonate above the register break, which, for tenors, is roughly situated between D4 and F4.

However, with the advent of modern research techniques in voice science, the validity of the systematic use of falsetto, and, by extension, register-blending exercises to develop the legitimate head voice has been questioned by prominent voice teachers. For example, the prolific and highly influential author of books on vocal pedagogy, Richard Miller (1993, 60-61), states that any attempt at blending falsetto into the rest of the voice is a "futile practice that stems from a misunderstanding of the physiologic events of falsetto". Other opponents of register blending or unification maintain that the correctly-produced human voice consists of only one register throughout its entire range (Marafioti 1941, 51, Vennard 1968, 6), and ascribe any timbral or perceptual registration shifts to resonance phenomena (R. Miller 2000, 26-27).

A degree of divergence in pedagogical ideas around vocal registration can be explained by the practical nature of the teaching process (D. G. Miller 2000, 41, Regidor Arribas 2016, 3). Many idiosyncratic vocabularies have been developed over the centuries as a means of guiding students by evoking the perceptual qualities that need to be developed during vocal training (McCoy 2012, 144). However, as I will show in Chapter 3, certain pedagogical disagreements go beyond mere semantics. This is especially true where register-blending or -unification exercises are aimed at developing and/or modifying the voice source mechanism as a means of solving the register problem. The pedagogical debate regarding the validity of such interventions at voice source level (which I would call mechanistic register training, to coin a term) goes to the heart of tenor training methods, and, therefore, warrants deeper investigation.

1.4. Methodology

Despite the enduring and universal recognition of the empirical existence of vocal registers, writings on vocal pedagogy, even well into the twentieth century, are characterised by great confusion in terminology[5] and widely diverging pedagogical ideas. This presents a challenge in the performance of a comparative analysis of texts on vocal pedagogy. It is necessary therefore to define a number of key

[5] A literature survey by Mörner, et al. (1963), found the use of over a hundred terms for voice registers.

scientific, physiological and pedagogical concepts for use as a type of "Rosetta stone" to interpret the confusing, and often conflicting, proliferation of pedagogical ideas.

The limited scope of this dissertation does not permit a lengthy exposition of all the physiological, scientific and pedagogical concepts that are relevant to the present research. The Glossary and overview of high-level concepts that follow are of necessity succinct and based on the assumption that the reader has a certain degree of prior knowledge of this field of study.[6]

1.4.1. Glossary

Note: Terms defined under separate entries in the Glossary are indicated in *italics*.

Abduction: The process of drawing the vocal folds apart for the purposes of breathing. See Figure 1, Figure 4(b), *Arytenoid cartilages* and *Posterior cricoarytenoid muscles*.

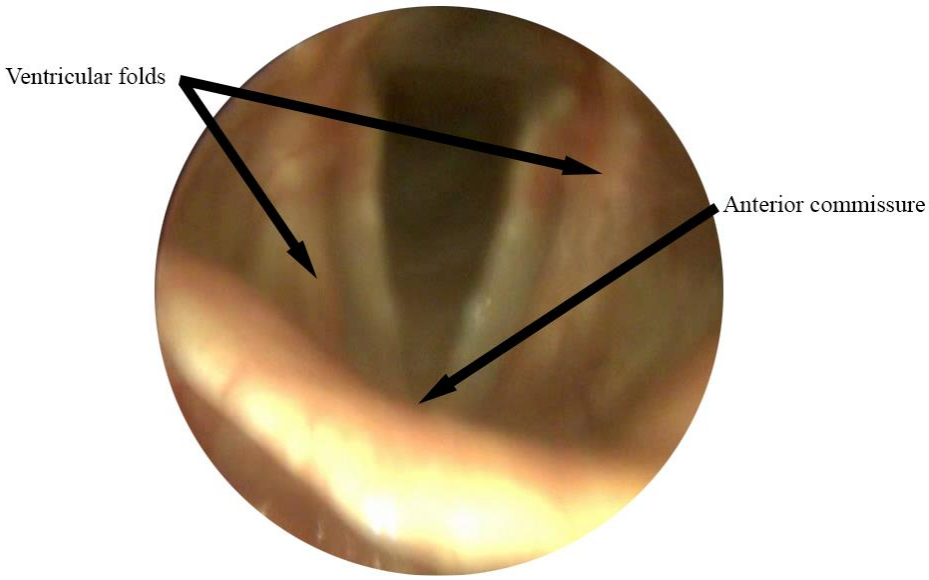

Figure 1: Laryngoscopic view of the author's vocal folds while abducted for breathing. The vocal folds cannot separate at the point of attachment to the thyroid cartilage (the anterior commissure), resulting in a triangular-shaped glottis during full abduction.

Adduction: The process of drawing the vocal folds together for the purposes of valving or phonation. See Figure 2, Figure 4(c), *Arytenoid cartilages*, *Interarytenoid muscle* and *Lateral cricoarytenoid muscles*.

[6] Modern voice science is truly multidisciplinary, straddling the fields of biology, physics, mathematics, acoustics, psychoacoustics and engineering.

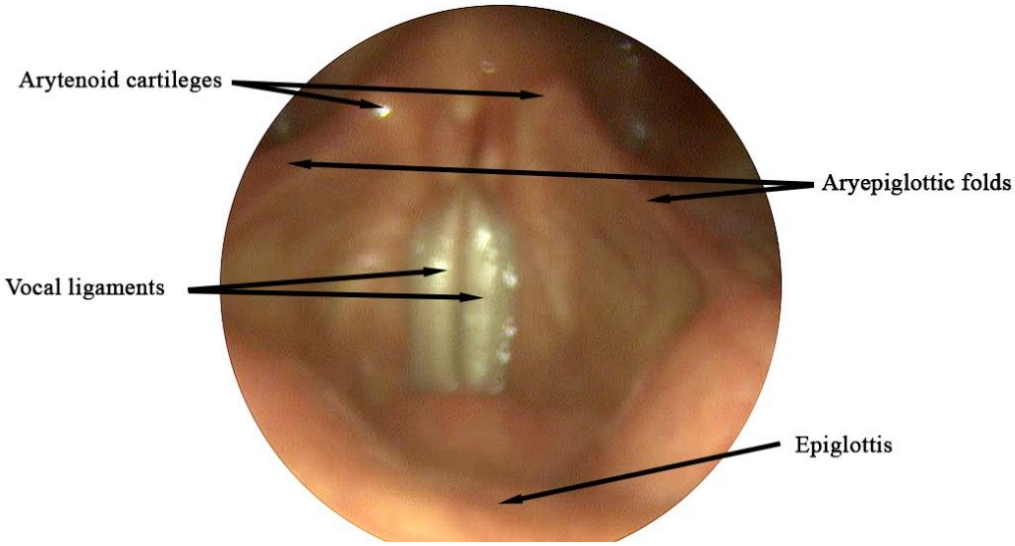

Figure 2: Laryngoscopic view of the author's vocal folds during normal chest voice phonation.

Aryepiglottic sphincter: A continuous band of muscle within the *aryepiglottic folds* that surrounds the *laryngeal inlet*. Contraction of this band of muscle produces a complex sphincter action, which closes the laryngeal inlet by pulling the *arytenoid cartilages* forward towards the *epiglottis*, adducting the aryepiglottic folds, and lowering the epiglottis (Pretterklieber, 2003, p. 254).

Arytenoid cartilages: Paired pyramid-shaped cartilages which perch on top of the posterior plate of the *cricoid cartilage*. The medial (vocal) processes of these cartilages form the posterior attachment sites for the *vocal ligaments*, while the lateral (muscular) processes are attachment sites for the *lateral cricothyroid muscles* (see Figure 3). The arytenoid cartilages perform a combined swivelling and rocking motion that serves to *abduct* and *adduct* the vocal folds under the action of the relevant intrinsic laryngeal muscles (Appelman 1986, 46, Rubin 2018, 5, Zemlin 1968, 120, Simpson and Rosen 2008, 3). See Figure 4 (b) and (c).

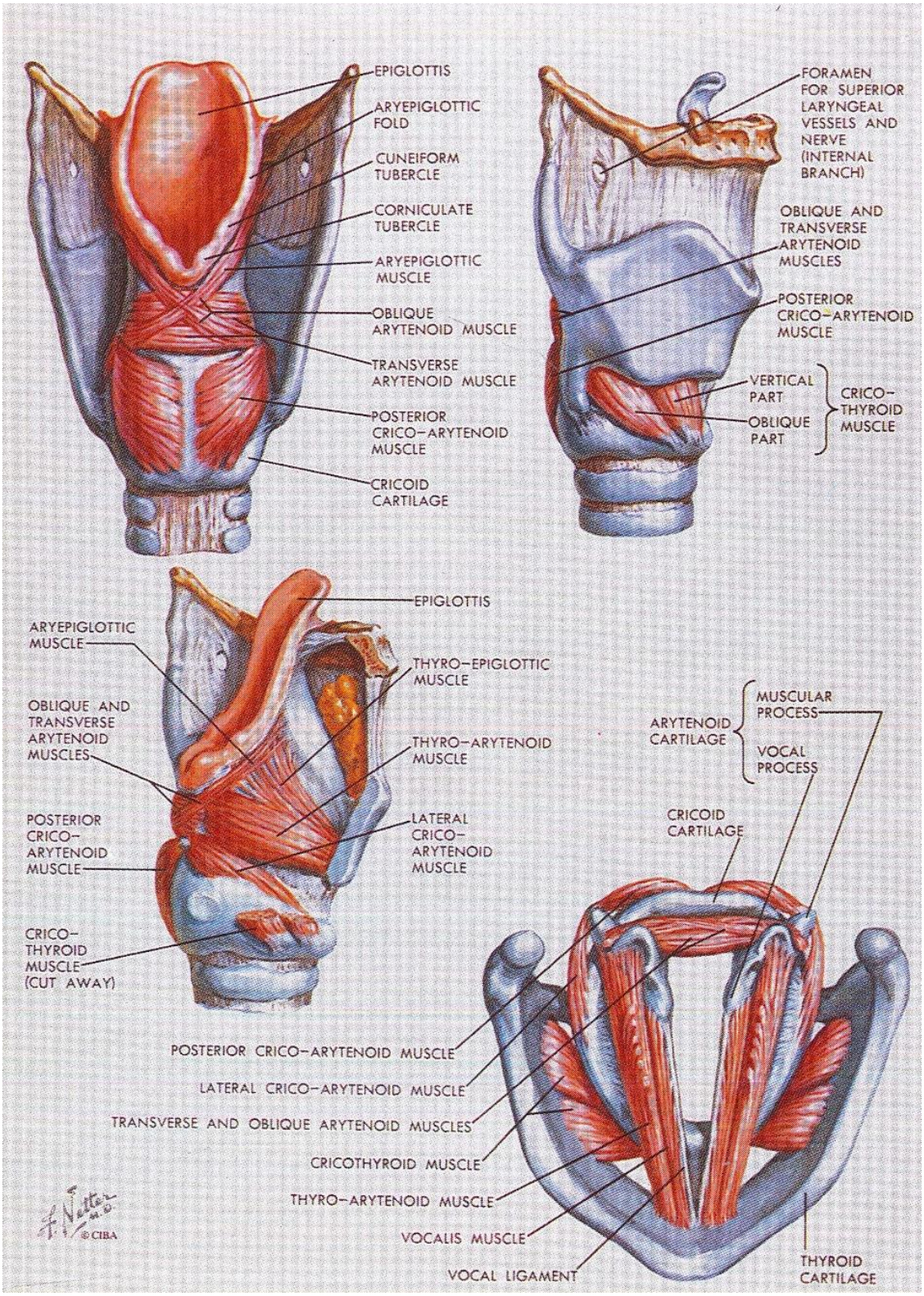

Figure 3: The intrinsic musculature of the human larynx. Source: Davies and Jahn (2004, 57).

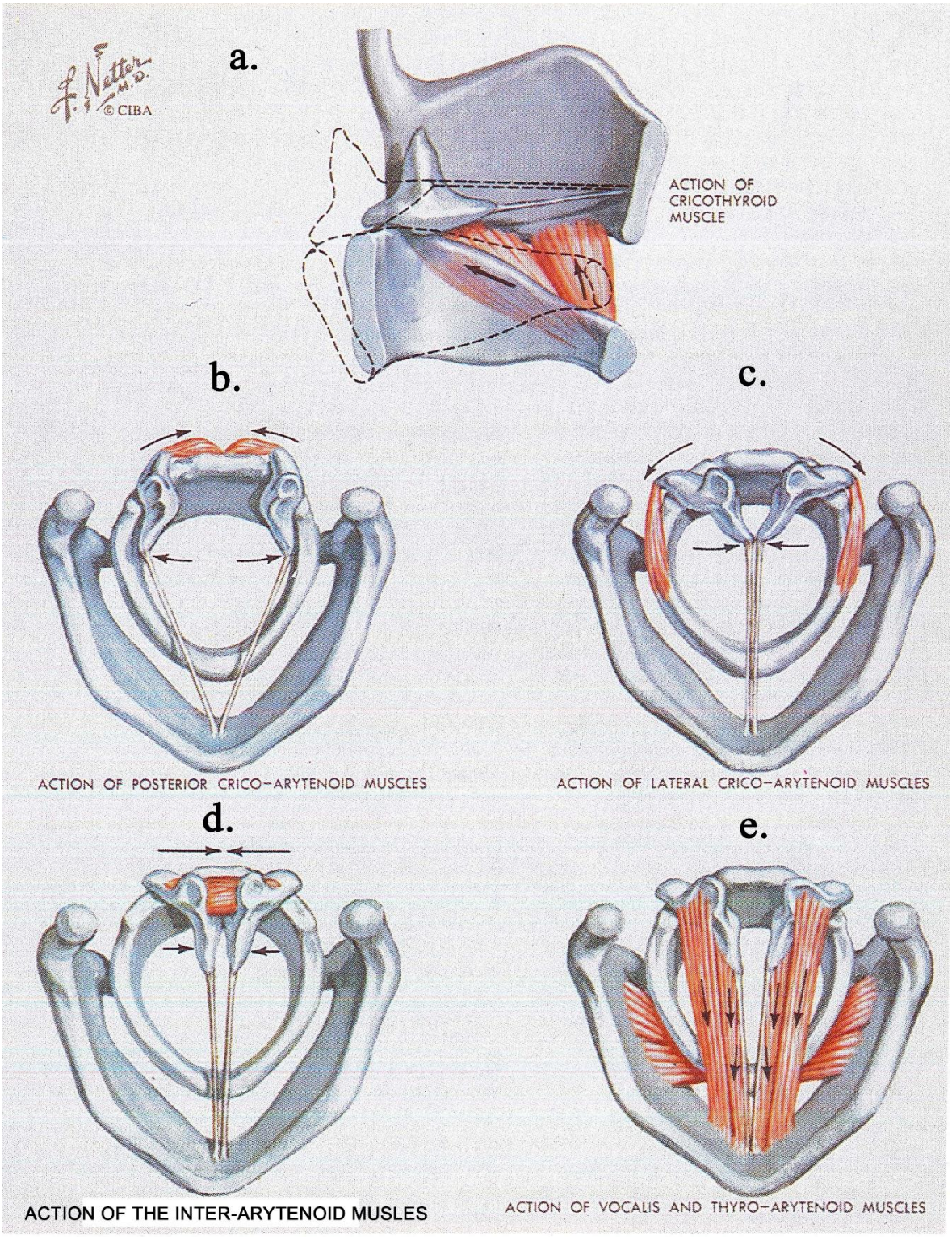

Figure 4: The actions of the intrinsic laryngeal musculature. Source: Davies and Jahn (2004, 58).

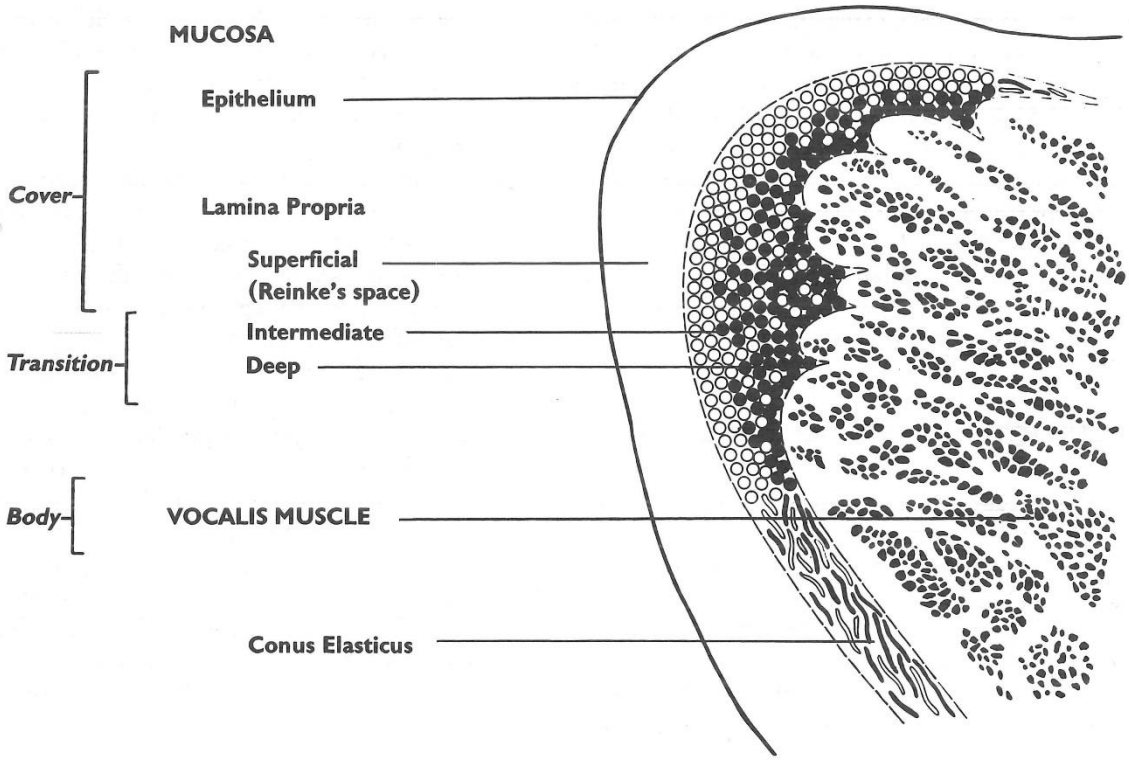

Figure 5: Schematic representation of an adult human vocal fold in coronal section, showing the five histological layers grouped into two functional units (the vocal fold body and cover, separated by a transitional layer) in accordance with Hirano's body-cover model. Source: Hirano and Bless (1993, 24)

Body-cover model: The model of vocal mechanics formulated by Minoru Hirano in 1974, which divides the five tissue layers of the vocal folds into two functional units, namely the *vocal fold cover* and *vocal fold body*, which are separated by a transitional layer. The vocal fold body, comprising the main mass of the *vocal folds*, consists of muscle tissue, which has active contractile properties. The *vocal fold cover* is passive tissue without any contractile properties. Furthermore, the *vocal fold cover* is filled with a gel-like substance and has a loose attachment to the *vocal fold body*, which allows the propagation of a bottom-to-top waving motion (the *mucosal wave*) in the vocal fold cover during normal chest-voice phonation (Miri 2014, 658, Titze 1994, 1412). See Figure 5.

Chest voice (as perceptual quality): The perceptual quality of the chest register can be described as the rich, full-bodied tonal quality that is associated with the normal speaking voice (Titze 2014, 2091, Thurman, et al. 2004, 18, 20). Quantitatively, the perceptual quality of chest voice is characterised by an inversion of the amplitude of H_1 (F_0) and H_2 and an abundance of overtone energy, which is evidenced by a shallow spectral slope as shown in Figure 6 (Titze 2014, 2091, Austin 2005, 244, Neiman, et al. 1997, 3, Titze 1994, 255-256).

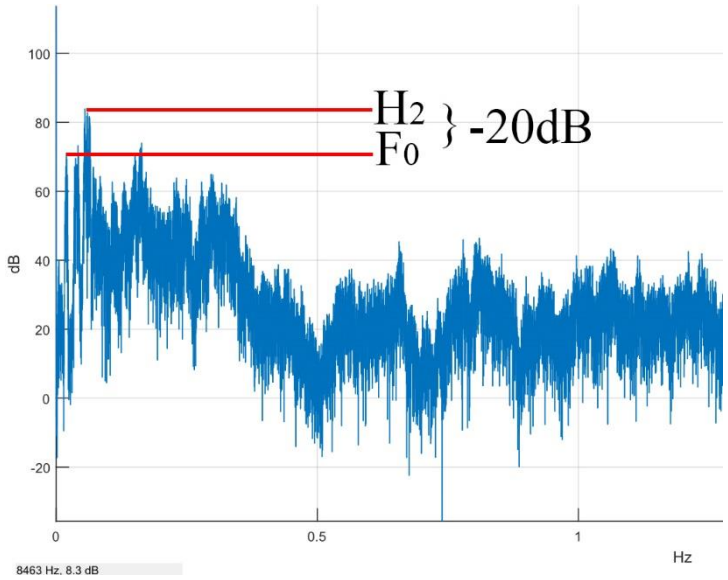

Figure 6: Typical power spectrum of a chest voice tone (sung by the author and analysed with AaltoAparat software), showing greater amplitude for H_2 than H_1 (F_0) (-20 dB) and a relatively shallow spectral slope for the upper harmonics.

Chest voice source mechanism (M1): The laryngeal mechanism or configuration which produces the chest voice perceptual quality. Its defining characteristic is the simultaneous presence of two vibrational modes during phonation, namely the medial-to-lateral motion of the *vocal fold body* and bottom-to-top waving motion in the *vocal fold cover* (see Figure 8). The waving motion in the vocal fold body (*mucosal wave*) requires a minimum threshold of vertical vocal fold thickness, as well as a shortening of the vocal folds to sufficiently slacken the vocal fold cover. This thickening and shortening of the vocal folds is an effect of *TA muscle* contraction (Vilkman, Alku and Laukkanen 1995, 70-71), which also creates the distinctive "squaring" or flattening of the medial vocal fold surface, seen in coronal section in Figure 7(b) (Titze 1994, 262).

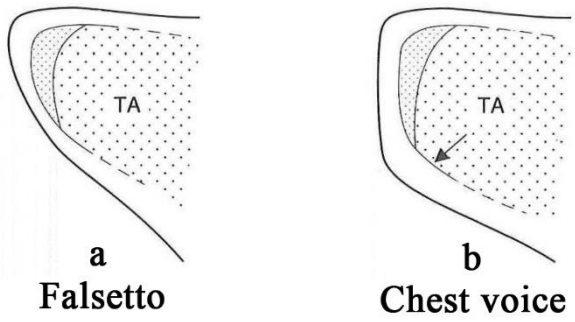

Figure 7: (a) Vocal fold shape for falsetto (M2) and (b) chest voice (M1) in coronal section. The flattened medial surface of the vocal fold in chest voice is the result of medial bulging of the contracting TA muscle. Source: Tize (1994, 262).

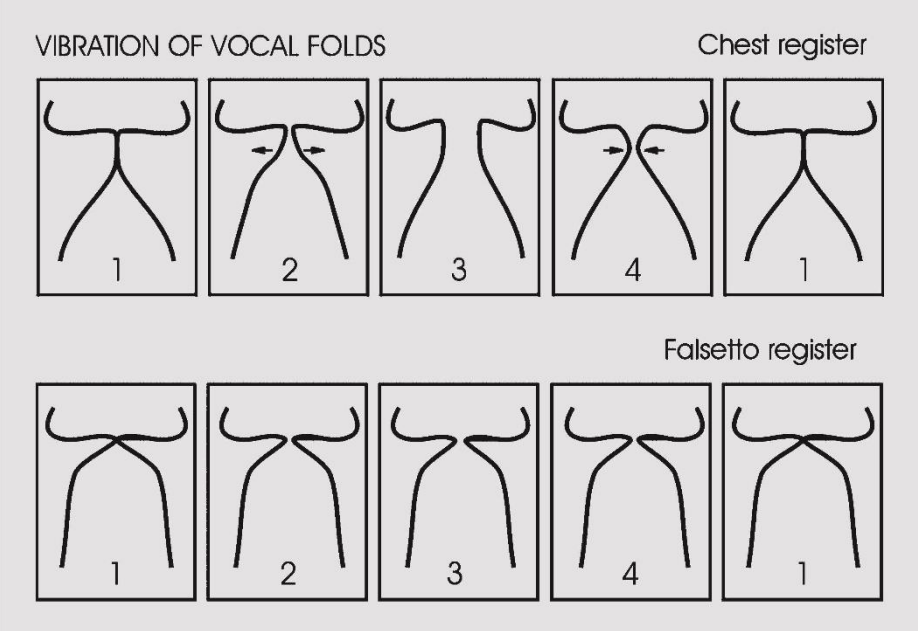

Figure 8: Simplified schematic representation of the distinct vibratory patterns of the vocal folds when phonating in chest (M1) and falsetto (M2) registers, as viewed in coronal section. Source: Miller and Schutte (2005, 279).

Conus elasticus: The thick layer of elastic membrane which lines the interior of the larynx from the *cricoid cartilage* to the *vocal folds* (Sataloff 2006b, 33-34). Functionally, it forms part of the *vocal fold body*. See *also Vocal fold cover* and *Vocal ligaments*.

Cricoid cartilage: A signet ring-shaped cartilage which is firmly attached to the *trachea* and *oesophagus* (Zemlin, 1968, p. 120). Forming the base of the larynx, it provides essential rigidity to the larynx as a whole, while also forming the foundation on which the rest of the laryngeal framework, consisting of the *thyroid* and *arytenoid cartilages*, is built (Rubin, 2018, p. 5). See Figure 4.

Cricothyroid (CT) muscle: Paired muscle which originates on the exterior of the *cricoid cartilage* and inserts into the exterior of the *thyroid cartilage*. Contraction of the CT muscle tilts the thyroid cartilage forward relative to the cricoid cartilage, thereby stretching, lengthening and thinning the vocal folds, while also tensing the vocal fold cover (Cooper, et al. 1993, 70, Hollien 2014, 399) – see Figure 4(a). The CT muscle is the main antagonist of the *TA muscles*.

CT dominance: A state of differential TA-CT muscle activation where the *CT muscle* is more active than the *TA muscle*. This configuration is hypothesised by some to constitute the *falsetto voice source mechanism (M2)* (Kochis-Jennings, et al. 2014, 652.e28-652.e29). See *TA-CT dominance theory*.

CT muscle: See *Cricothyroid muscle*.

Epiglottis: The leaf-shaped cartilage which forms the anterior boundary of the *laryngeal inlet* and closes over the laryngeal inlet like a lid during swallowing (Simpson and Rosen 2008, 4).

External laryngeal muscles: A collective term for the so-called extrinsic strap or sling muscles which form a suspension system that allows the larynx to float in relation to the skeleton (R. Miller 1986, 242, Titze 1994, 4).

F_0: Abbreviation for *fundamental frequency*.

F_1, F_2 etc.: Abbreviations for the various formant frequencies. See *Formants*.

Falsetto (as perceptual quality): Used to refer to the light, flute-like quality reminiscent of the pre-pubescent voice, which males and females can produce in their upper vocal range. Quantitatively, it is characterised by H_1 (F_0) having a higher amplitude than H_2, as well as relatively weak overtone energy, which is evidenced by a steep spectral slope as shown in Figure 9 (Titze 2014, 2091, Thurman, et al. 2004, 18, 20).

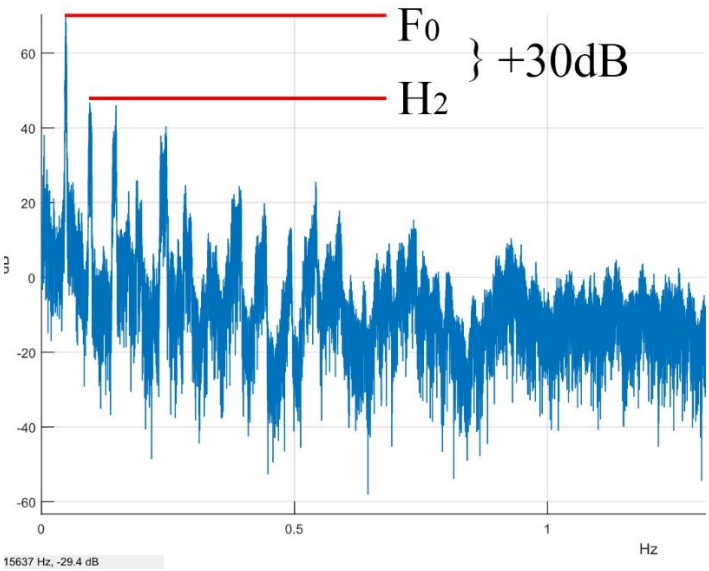

Figure 9: Typical power spectrum of a falsetto tone (sung by the author and analysed with AaltoAparat software), showing greater amplitude for H_1 (F_0) than H_2 (+30 dB) and a steeply declining spectral slope for the upper harmonics.

Falsetto voice source mechanism (M2): The laryngeal mechanism or configuration which produces the *falsetto* perceptual quality (Henrich Bernardoni, Smith and Wolfe 2014, 491). Its defining characteristic is a negligent, or completely absent, *mucosal wave* in the *vocal fold cover* (see Figure 8). In this configuration, the vocal folds are elongated under the action of the *CT muscle*, with a simultaneous

release of the antagonist *TA muscle* to the point where the *vocal fold cover* is so stretched and stiff that there is minimal aerodynamic deformation, and so thin that no vertical phase difference can develop. As a result, only the medial-to-lateral oscillatory motion is present (Vilkman, Alku and Laukkanen 1995, 70-71). In addition, the low level of TA muscle activity causes the TA muscle to fall to the side of the larynx, resulting in the typical convergent shape shown in coronal section in Figure 7(a) (Titze 1994, 261-262).

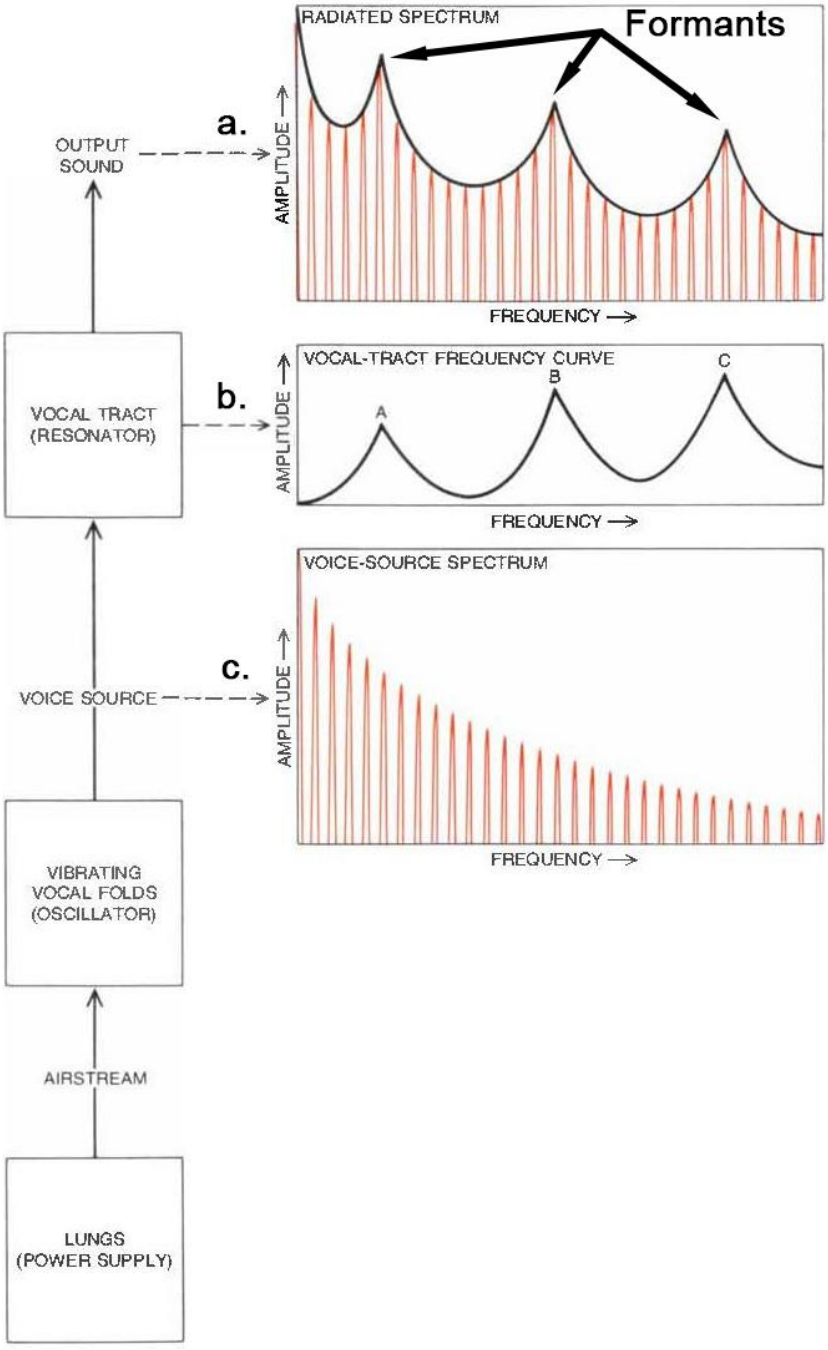

Figure 10: Modification of the voice source by vocal tract resonance. Source: Sundberg (2001, 84)

Formants: The regions of resonance frequencies in the human *vocal tract* that selectively amplify the *harmonics* (overtones) inherent in the voice source. The human vocal tract has four or, under certain conditions, five main natural resonance frequencies, which are designated as F_1 to F_5 from the lowest frequency upwards, presenting as *amplitude* peaks in a typical spectrogram, such as the one in Figure 10 (McCoy 2012, 40, Sundberg 1977, 82).

Glottal airstream: The air that passes through the glottis to be converted into sound during phonation (Titze 1988, 1536).

Glottis: Short for *Rima glottidis*.

H1, H2, etc.: Abbreviations used for the fundamental frequency (H_1) and *harmonics* or overtones (H_2, H_3 etc.) of a musical tone (Moore 2013, 3).

Harmonics (overtones): The component sine waves of a periodic complex sound (musical tone), which are integer multiples of the fundamental frequency (Baken 2006, 74-75, Vennard 1968, 6-8).

Head voice: Variously used as synonym for *falsetto* or as a general term for a singer's upper register.

Interarytenoid (IA) muscles: A collective term for the transverse and oblique arytenoid muscles that attach to the posterior facets of each *arytenoid cartilage* (see Figure 3). Contraction of these muscles assists in *adduction* by drawing the *arytenoid cartilages* together (Simpson and Rosen 2008, 5). See Figure 4(c).

Internal thyroarytenoid muscle: See *Vocalis muscle*.

Laryngeal inlet: The superior inlet to the larynx, which is formed laterally by the *aryepiglottic folds*, anteriorly by the *epiglottis*, and posteriorly by the *arytenoid cartilages*. These structures form a collar or wall-like enclosure around the *laryngeal tube* or vestibule (Vennard, 1968, p. 89; Appelman, 1986, p. 49). See *Aryepiglottic sphincter*.

Laryngeal tube (vestibule): A roughly tubular space, approximately two centimetres in height, between the *vocal folds* and the *laryngeal inlet*. It forms a closed resonating system which is extremely important in classical vocal technique due to its role in the production of the so-called *singer's formant* (Appelman 1986, 49, Vennard 1968, Sundberg 1972, 46, Titze 1994, 239-240).

Lateral cricoarytenoid (LCA) muscles: The paired muscles which originate on the superior border on either side of the *cricoid cartilage* and insert into the lateral (muscular) process of the *arytenoid cartilages*. Contraction the LCA muscles causes the arytenoid cartilages to rock forward and swivel

inwards, thereby drawing the vocal processes together to adduct the *vocal folds*. The *IA muscles* assist with this adductory motion (Simpson and Rosen 2008, 4-5)**.** See Figure 4**(**c).

LCA muscle: See *Lateral cricothyroid muscles*.

Legitimate head voice: A term coined by Richard Miller (1986, 118) to refer to the chest-voice-like upper extension of the tenor voice. The *voice source mechanism* of the legitimate head voice is uncertain, but is widely hypothesised to consist of a mixture of the *chest* and *falsetto voice source mechanisms* (Van den Berg 1968, 132, Celetti 1991, 113). See *Mixed voice source mechanism (M2A)*.

M0, M1, M2 and M3: The number-based denomination of voice source mechanisms, respectively associated with pulse register (M0), *chest voice* (M1), *falsetto* (M2) and flute register (M3), developed by Henrich et. al. (2003, 3).

Mixed voice (perceptual quality): A tonal quality that sounds like a mixture of *chest voice* and *falsetto* (Van den Berg 1968, 132).

Mixed voice source mechanism (M2A): The hypothesised hybrid mechanism that purportedly partakes of both *chest voice* (M1) and *falsetto* (M2) (Thurman, et al. 2004, 6-7). There is no scientific evidence of the existence of mixed voice as an independent or hybrid mechanism (Castellengo, Chuberre and Henrich 2004), but it is nevertheless widely believed that the tenor's *legitimate head voice* is produced in this manner.

Mucosal wave: The cyclical wave-like deformation pattern in the *vocal fold cover* caused by the transfer of aerodynamic energy from the *glottal airstream* to the *vocal fold cover* (Harris and Moisik 2018, 21). The presence of the mucosal wave is a defining characteristic of the *chest voice source mechanism*, while its absence is a defining characteristic of the *falsetto voice source mechanism* (Vilkman, Alku and Laukkanen 1995, 70-71).

Myoelastic-aerodynamic theory: The generally accepted theory that explains vocal fold vibration in terms of three component forces, namely those provided by muscle contraction (specifically the LCA and TA muscles that produce *adduction*), the elastic properties of the laryngeal muscles and ligaments, and the aerodynamic forces inherent in the *glottal airstream* (Titze 1994, 80-81, Vennard 1968, 42, Van den Berg 1968, 129).

PCA muscle: See *Posterior cricoarytenoid muscles*.

Pharynx: The supraglottic vocal tract up to the nasal cavity. It is divided into three sections: the laryngopharynx (the space immediately above the glottis), bucopharynx (pharyngeal space behind the

tongue up to the soft palate) and nasopharynx (the rear of the nasal cavity, above the soft palate). These three spaces correspond with three pharyngeal muscles which act as sphincters when contracted (Sataloff 2006b, 51, 54). Due to its importance in vocal resonance, it is considered good classical vocal technique to keep the pharyngeal muscles relaxed to maintain a large pharyngeal space (Vennard 1968, 98).

Posterior cricoarytenoid (PCA) muscle: The main abductor muscle. It originates on the posterior plate of the *cricoid cartilage* and inserts into the posterior facet of each *arytenoid cartilage*. Contraction of the PCA muscle simultaneously rocks the *arytenoid cartilages* backward and swivels them outwards, resulting in the opening of the *glottis* (Simpson and Rosen 2008, 5, 8). See Figure 1 and Figure 4(c) and *Abduction*.

Quadrangular membrane: A thick layer of elastic membrane which lines the interior of the larynx between the ventricular folds (false vocal cords) and *aryepiglottic folds*. It adjoins the *conus elasticus* below it; both membranes are covered by epithelial tissue which forms a continuous mucous membrane lining of the interior of the larynx (Sataloff 2006b, 34).

Register break: An involuntary register transition, accompanied by an uncontrolled frequency jump, which in the case of the tenor voice tends to occur around E4. Scientific research suggests that the register break between chest voice and falsetto can have more than one cause, such as insufficient strength of the *TA muscle* (Van den Berg 1968, 130), aerodynamic instabilities at the point of transition from chest voice to falsetto due to the different aerodynamic characteristics of the respective *voice source mechanisms* (Titze 1980, 499), and resonance interference where *formant* or subglottal frequencies cross over the fundamental frequency (Vennard 1968, 87-88).

Rima glottidis: The space between the *vocal folds* through which the *glottal airstream* passes. The glottis closes during *adduction* (whether this be for phonation or valving) and opens during *abduction* (Titze 1994, 26). Synonym for *glottis*.

Singer's formant: The clustering together of the third to fifth formants (F_3 to F_5) in the region of 3 kHz, which gives the characteristic ringing quality to a well-produced male operatic voice (Sundberg 1988, 14). It is this formant-tuning ability of the trained singer that allows him to project his voice over the much louder sound of an orchestra, given that the main acoustic energy of an orchestral sound is concentrated at around 450 Hz (Hunter, Švec and Titze 2006, 521, 525).[7]

[7] Interestingly, the natural resonance frequency of the human ear canal, which has a length of approximately 2.5 cm, is approximately 3,500 Hz, enabling it to amplify frequencies between 2,000 and 5,500 Hz by as much as

TA dominance: A state of differential TA-CT muscle activation where the *TA muscle* is more active than the *CT muscle*. This configuration is hypothesised by some to constitute the chest voice source mechanism (M1) (Kochis-Jennings, et al. 2014, 652.e28-652.e29).

TA muscle: see *Thyroarytenoid muscle*.

TA-CT dominance theory: A theory which attempts to define the registers in terms of the underlying action of laryngeal muscles (specifically the TA-CT antagonist pair), as opposed to the vibrational patterns that result from such action (Kochis-Jennings, et al. 2014, 652.e28-652.e29). Notwithstanding the existence of cogent empirical evidence disproving this theory (Hull 2013, 39, Kochis-Jennings, et al. 2014, 652.e29), it has had significant influence on pedagogical ideas. See Figure 11, *TA dominance* and *CT dominance* and Chapter 3.

Figure 11: Schematic representation of TA-CT dominance theory.

Thyroarytenoid (TA) muscle: A paired muscle, consisting of an internal belly, variously called the internal thyroarytenoid muscle, thyrovocalis muscle (or *vocalis* muscle for short), and an external belly, variously called the external thyroarytenoid or thyromuscularis muscle. Contraction of the *TA muscle* tends to shorten and thicken the *vocal folds*, thereby slackening the *vocal fold cover*, which is associated both with lowered pitch and *chest voice* phonation (Cooper, et al. 1993, 70). The *TA muscle* is the primary antagonist of the *CT muscle* (Pretterklieber 2003, 254, Appelman 1986, 56, Cooper, et al. 1993, 70, Sataloff 2006a, 42, Simpson and Rosen 2008, 5). See Figure 3 and Figure 4.

Thyroid cartilage: This cartilage, referred to colloquially as the Adam's apple, can easily be seen and felt as an anterior protrusion in the throat. It performs a visor-like, rotational motion relative to the *cricoid cartilage*, which serves primarily to adjust the length and tension of the *vocal folds* when adducted (Cooper, et al. 1993, 70), which in turn forms an essential part of the pitch-changing mechanism (Simpson and Rosen 2008, 4). See Figure 4(a).

20 dB (Warren 2008, 7, 22, Sataloff 2006a, 11). This region of maximum auditory sensitivity correlates with the singer's formant in the male voice, as well as a cluster of F0 and F1 in the female voice (Hunter, Švec and Titze 2006, 521-523), which might lead one to speculate that the human ear has evolved to be tuned specifically to a well-produced human voice. Thus, humans are able to "hear out" the sound of other human voices from a mix of ambient sounds.

Vibratory modes (patterns): The *vocal folds* are capable of two vibrational modes, namely a repeated medial-to-lateral oscillatory motion, and a bottom-to-top waving oscillatory motion. The former occurs in the *vocal fold body*, while the latter is a surface tissue phenomenon that occurs in the *vocal fold cover* when it is sufficiently slack and pliable to be susceptible to aerodynamic deformation (Thurman, et al. 2004, 10). See *Mucosal wave*, *Chest voice source mechanism (M1)* and *Falsetto voice source mechanism (M2)*.

Vocal fold body: The muscular portion of the *vocal folds* (consisting of the *vocalis* and *external thyroarytenoid muscle*), which is distinguished from the *vocal fold cover* on the basis of its active contractile properties (Chhetri, et al. 2009, 222). See *Body-cover model*.

Vocal fold cover: The superficial layer of the *vocal folds*, consisting of the superficial ligamentous layer and epithelium (mucus membrane). The vocal fold cover is characterised by its loose attachment to the *vocal fold body*, as well as the fact that it consists of passive tissue without any inherent contractile properties (Vahabzadeh-Hagh, Zhang and Chhetri 2018, 1412).

Vocal ligaments: The thickened, free upper borders of the *conus elasticus*, which form the superior ligamentous edges of the *vocal folds*, which are visible as two white bands on either side of the *glottis* when the larynx is viewed from above (Appelman 1986, 47-48, Vennard 1968, 55, Sataloff 2006b, 34). See Figure 2, Figure 4(b) and Figure 4(c).

Vocalis muscle: The internal belly of the *thyroarytenoid muscle* which forms the lower edge of the *vocal fold body*. See Figure 5.

Vowel formants: This refers to the first and second formants (F_1 and F_2), whose frequencies can be moved up or down through various articulatory gestures (configurations of the tongue, lips, jaw and pharynx), as a means of controlling the perceptual qualities that are associated with distinct vowel sounds (McCoy 2012, 41-42, Sundberg 1977, 83). The relative pitches of the formants in the cardinal vowels are shown in Figure 12. The lower pitch shown for each vowel corresponds to F_1, while the higher pitch corresponds to F_2.

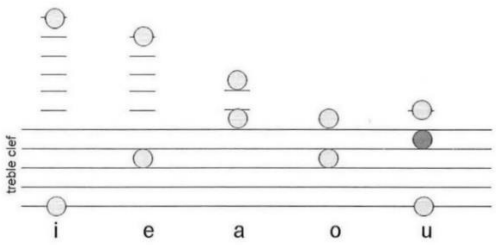

Figure 12: The relative pitches of F_1 (the lower pitch) and F_2 (the higher pitch) of the cardinal vowels, notated in the treble clef. Source: McCoy (2012, 45)

1.4.2. Vocal physiology

The larynx can be thought of as consisting of four anatomical units: the skeleton (cartilages), intrinsic musculature, extrinsic musculature and mucosa (Sataloff 2006b, 26). The components of the larynx that are relevant to the present research are defined in the Glossary.

The vocal folds can be described as flaps of tissue, resembling lips, which lie horizontally in the larynx and run in an anterior-posterior direction (Titze 1995, 38). Their function during phonation is to modulate expiratory airflow to create pressure waves, which are heard as sound (Sell 2005, 76, Titze 1995, 38).

The laryngeal structure as a whole is suspended from the base of the skull and jaw by a set of extrinsic laryngeal muscles (Rubin 2018, 4). The vertical position of the larynx in relation to fixed skeletal elements such as the cervical vertebra (Hurme and Sonninen 1995, 1) is subject to voluntary control through the differential action of the extrinsic laryngeal muscles,[8] having a range of vertical travel of several centimetres (Titze 1994, 4).

The supra-laryngeal structure, referred to as the vocal tract, forms a roughly tubular channel from the vocal folds to the lips. It includes the laryngeal tube, laryngopharynx, bucopharynx, nasopharynx, and mouth cavity. The articulatory organs (lips, tongue, jaw, pharynx, soft palate, hard palate and teeth) are used to modify the shape of the vocal tract to influence vocal resonance and control the vowel shapes (Sataloff 2006b, 51-52).

1.4.3. Perceptual parameters of a vocal tone

Titze (1994, 252) identifies four broad perceptual parameters of the human voice, namely pitch, loudness (volume), vowel identity and quality (timbre). Of these, timbre and – to a lesser extent – pitch are the most relevant to the present research.

The relevance of timbre to the present research stems from the fact that listeners identify vocal registers primarily according to perceptual quality. The "legitimacy" of a tenor's upper register is similarly judged according to its perceptual quality. The perceptual quality of a vocal tone is determined by the

[8] The extrinsic laryngeal muscles are divided into two functional groups, namely the elevator and depressor muscles. The elevator muscles include the digastric, thyrohyoid, stylohyoid, geniohyoid and mylohyoid muscles, while the depressor muscles are comprised of the sternothyroid, sternohyoid and omohyoid muscles (R. Miller 1986, 249-252)

biomechanical action of the vocal folds as well as the resonance properties of the vocal tract, as explained in 1.4.4 below.

Pitch (SPN)	Frequency (Hz)	Pitch (SPN)	Frequency (Hz)
C_2	65.41	C_4	261.63
C#2/Db2	69.30	$C^{\#}_4/D^{b}_4$	277.18
D2	73.42	D_4	293.66
D#2/Eb2	77.78	$D^{\#}_4/E^{b}_4$	311.13
E2	82.41	E_4	329.63
F2	87.31	F_4	349.23
F#2/Gb2	92.50	$F^{\#}_4/G^{b}_4$	369.99
G2	98.00	G_4	392.00
G#2/Ab2	103.83	$G^{\#}_4/A^{b}_4$	415.30
A2	110.00	A_4	440.00
A#2/Bb2	116.54	$A^{\#}_4/B^{b}_4$	466.16
B2	123.47	B_4	493.88
C_3	130.81	C_5	523.25
$C^{\#}_3/D^{b}_3$	138.59	$C^{\#}_5/D^{b}_5$	554.37
D_3	146.83	D_5	587.33
$D^{\#}_3/E^{b}_3$	155.56	$D^{\#}_5/E^{b}_5$	622.25
E_3	164.81	E_5	659.25
F_3	174.61	F_5	698.46
$F^{\#}_3/G^{b}_3$	185.00	$F^{\#}_5/G^{b}_5$	739.99
G_3	196.00	G_5	783.99
$G^{\#}_3/A^{b}_3$	207.65	$G^{\#}_5/A^{b}_5$	830.61
A_3	220.00	A_5	880.00
$A^{\#}_3/B^{b}_3$	233.08	$A^{\#}_5/B^{b}_5$	932.33
B_3	246.94	B_5	987.77

Table 1: Table of the pitches in the human vocal range and their corresponding frequencies. A4 = 440 Hz. Source: after Suits (Tuning n.d.).

Pitch, being the subjective correlate of the fundamental frequency of a tone (Moore 2013, 2), is conceptually and physiologically interconnected with the voice register: As is readily observable, the lower part of any healthy voice, which includes the normal speaking voice range, is naturally produced in chest voice, while an untrained voice will tend to switch to falsetto for notes that go beyond its innate chest voice range. Furthermore, the physiological control of both pitch and register are dependent on the differential action of the same two intrinsic laryngeal muscles, namely the CT and TA muscles. The SPN notations (see footnote 2 on p. 1) of the pitches in the human vocal range with corresponding frequencies are given in Table 1.

Loudness is the subjective perception of the intensity (acoustic energy) of a sound (Sataloff 2006a, 9), while vowel identity results from the perception of various distinctive phonetic qualities created by

resonances in the vocal tract (see Glossary definitions of *Formants* and *Vowel formants*) (Bunch 1997, 99).

1.4.4. Source-filter theory

Source-filter theory has its origins in the definition of vocal registers as initially formulated by Manuel García (quoted in sub-Chapter 3.3.3), which draws a clear conceptual distinction between the laryngeal vibrating system (voice source mechanism), the acoustic output of the voice source mechanism (voice source) and the modification of the voice source by the vocal tract resonance system (filter). In its original form, the relationship between these elements was postulated to be linear, meaning that the voice source mechanism and filter were assumed to function completely independently from each other (Fant 1960, 17). This formulation has since been superseded by non-linear source-filter theory, which postulates that the kinetic energy in the vibrating air column in the vocal tract and/or subglottal system can under certain circumstances feed back into the vibrating vocal folds to either assist or interfere with their vibratory behaviour (Titze 1988, 1537-1538, Zhang 2016, 2620) – see sub-Chapters 4.2.1 and 4.3.3.

1.4.5. Voice source mechanisms

The term, laryngeal or voice source mechanism is used to refer to the various biomechanical conditions of the larynx that are typical of the respective vocal registers. In a strict sense, there is only one laryngeal mechanism (Vahabzadeh-Hagh, Zhang and Chhetri 2018, 1412), which is comprised of the cartilages, muscles and connective tissue referred to in 1.4.2 above. Consequently, the term in question should be viewed as shorthand for a set of distinct configurations of the various elements of the larynx that play a causal role in the production of each register.

Science has identified four main voice source mechanisms (corresponding to four registers) on the basis of distinct vibrational modes, which are denominated as M0 (pulse register), M1 (chest voice), M2 (falsetto) and M3 (flute register) (Henrich, Roubeau and Castellengo 2003, 3). Of these, only M1 and M2 are relevant to the present research, as these are the main voice source mechanisms that are used in singing (Thurman, et al. 2004, 6-7). The postulated mixed voice mechanism (M2A) is also relevant as the purported mechanism of the tenor's legitimate head voice (Thurman, et al. 2004, 6-7). As such, M2A is closely linked to the old-school practice of register-blending or -unification.

The main parameters that determine laryngeal configuration are the length, stiffness and thickness of the vocal folds. These three parameters are determined by the differential action of the CT and TA muscles, which can briefly be described as follows:

1. Vocal fold length is primarily controlled through the action of the CT muscle. Contraction of this muscle results in a stretching, lengthening and thinning of the vocal folds, which is associated with rising pitch (see motion described in the Glossary under *Crycothyroid muscle* and *Thyroid cartilage*). As such, the CT muscle is often referred to as the "pitch agent" (Simpson and Rosen 2008, 5, Appelman 1986, 54-55, Vennard 1968, 55, Sataloff 2006b, 29, 46).
2. Vocal fold stiffness is similarly a product of CT muscle action, given that the vocal folds (especially the vocal fold cover) become stiffer as the vocal folds are stretched under the action of this muscle (Story and Titze 1995, 1251). However, it is theoretically possible, through the differential activation of the CT and TA muscles, to produce a wide range of stiffness conditions in the vocal folds without changes in elongation (Titze 1994, 194), which may explain how it is possible to phonate in chest voice at high pitches.
3. Vocal fold thickness is primarily controlled through the action of the TA muscle. Being the main antagonist to the CT muscle, TA muscle contraction also tends to shorten the vocal folds, which results in a concomitant slackening of the vocal fold cover (Vilkman, Alku and Laukkanen 1995, 70-71). The combination of increased thickness in the vocal fold body and increased slackness in the vocal fold cover creates the necessary conditions for propagation of the mucosal wave. Release of this muscle is associated with the falsetto voice source mechanism, given that the relaxed TA muscle falls to the side of the larynx, resulting in the permanent convergent glottal shape which is typical of falsetto (See Figure 7(a)), while also releasing the antagonist force that counteracts the vocal-fold-stretching effect of CT muscle contraction. As such, the TA muscle is often referred to as the "register agent" (Austin 2005, 242).

1.4.6. Register terminology

The term vocal register (or register for short) is commonly defined as a continuous series of vocal tones with a uniform perceptual quality that are produced with the same voice source mechanism (Titze 1994, 253, Garcia 1847a/1985, 6). While this provides a useful point of departure, it is important to note that the relationship between voice source mechanism and perceptual quality is complex. As shown in the previous section, the harmonic structure of a vocal tone[9] is the product of the acoustic spectrum of the voice source as well as the resonance properties of the vocal tract, which makes it inherently difficult to untangle their respective contributions (Henrich Bernardoni, Smith and Wolfe 2014, 492). The

[9] A vocal tone, like all sounds in nature, is a complex sound which is composed of several superimposed waveforms (Sataloff 2006a, 10). It is also an instance of sounds that are defined as musical tones, which have regular, repeating (periodic) wave patterns, as opposed to noise, which has a random pattern (Baken 2006, 74).

historical register terms which are used in this dissertation,[10] namely chest voice, falsetto, head voice and mixed voice, are generally used indistinctly to refer to the perceptual quality of a given register as well as the voice source mechanism through which it is produced. For the sake of convenience, I will not depart from this practice, but will use the number-based designations (M1, etc.) where necessary to explicitly refer to the voice source mechanism.

The terms register-blending and register-unification are often used interchangeably in the pedagogical literature. However, the eminent voice scientist, Ingo Titze (2018, 49), draws an important semantic distinction. According to this author, register-blending refers to a tonal adjustment that is made in the area around the register break (the *passaggio*) to achieve a smooth transition between chest voice and falsetto. Register-unification, on the other hand, assumes that it is possible through long and hard practice to merge the chest and falsetto registers into a single, continuous mechanism.

This analysis by Titze overlooks a third postulate that is encountered in the literature, namely that the chest voice and falsetto laryngeal mechanisms can be blended throughout the singer's range to produce a uniform and balanced tone quality. In such a voice, both mechanisms are engaged simultaneously in order to produce a unique and ideal blend of both registers for every note in the singer's range. This would result in the chest register being dominant in the lower parts of the voice, while dominance is gradually transferred to the falsetto register with rising pitch.

1.4.7. Framework for comparative analysis of pedagogical approaches

The preceding discussion suggests a potential classification of pedagogical approaches into the following four main strategies:

- **Strategy 1: multi-register singing with a smooth transition through "register-blending"**

  The singer is guided in the development of both his chest voice and falsetto, while learning to skilfully execute a smooth transition between the chest voice – which must be confined to its natural, lower compass – and falsetto, which is used for the upper range. In terms of this approach, the transition is disguised through vowel modification, as well as acoustic and dynamic adjustments, which result in a "blended" quality in the area of transition.

[10] Various proposals have been made for more scientifically valid register terminology (Hollien 1972, 2-3). However, the historical terms, chest voice, falsetto, head voice and mixed voice, continue to be used by pedagogues and scientists alike. Given their long-standing usage, these terms are deeply entrenched and their meanings well-understood in the scientific and pedagogical communities.

- **Strategy 2: blending of laryngeal mechanisms**

  The singer is guided to develop both his chest voice and falsetto, but is taught to engage both register mechanisms simultaneously with varying degrees of dominance appropriate to each given note. This strategy is distinguished from Strategy 1 by the fact that the register mechanisms are blended throughout the singer's vocal range as a means of achieving a uniform tonal quality throughout.

- **Strategy 3: unification of the registers**

  The singer is guided to develop both his chest voice and falsetto until both are equal in power and quality, at which point the two registers are merged into one. Proponents of this strategy are not clear on the physiological characteristics of this unified mechanism at laryngeal level, but logically such a unified voice may be produced either by:

  a) a single mechanism that is indistinguishable from chest voice, implying that the developed falsetto eventually transforms into chest voice;

  b) a hybrid mechanism which, though partaking of both chest voice and falsetto, is sufficiently unique to warrant definition as a separate mechanism; or

  c) a completely new and independent mechanism.

- **Strategy 4: the single-register approach**

  Here, the main focus is on the development of the singer's chest voice mechanism and learning how to extend his chest register upwards with the aim of using this voice source mechanism throughout his range. Proponents of this hypothesis do not deny that perceptual shifts in vocal quality take place as the singer ascends the scale, but maintain that such shifts result from necessary adjustments of vocal tract resonances, without changing voice source mechanism (D. G. Miller 2000, 45).

Strategy 1 is representative of the founding works of the Old Italian School of Singing dating from the seventeenth and eighteenth centuries, which were written mainly by castrati teachers. It remains a valid strategy for female voices, insofar as the largest part of the female vocal range (from F4 upwards) is produced with the vibratory mode that is typical of falsetto (D. G. Miller 2000, 51). While it is possible for female singers to circumvent the difficulty of register transitions by avoiding the use of the chest register for their low notes (Miller and Schutte 2005, 281), those who do make use of chest voice must necessarily find a way to disguise or smooth over the register transition. Modern research has shown that this is done through vowel modification, as well as acoustic and dynamic adjustments, which results

in a vocal quality that can be described as “mixed voice” in perceptual terms (Titze 2018, 49, D. G. Miller 2000, 62, Miller and Schutte 2005, 284-285).

In contrast, the “chesty” quality of the modern operatic tenor’s legitimate head voice implies that the mechanism at work in his upper register is qualitatively different from falsetto. As a result, Strategies 2, 3 and 4 start to emerge in writings from the nineteenth century onwards as pedagogues attempt to marry the old-school traditions with the changed vocality of the modern operatic tenor. These strategies remain well-represented in pedagogical writings from the twentieth century to the present, and the debate regarding their respective merits remains far from resolved.

The main body of this dissertation commences with a brief historical overview of the tenor voice, the evolution of tenor vocality, and the origins of the register-blending or -unification methods that form the focus of this dissertation (Chapter 2). This is followed by a comparative analysis of a selection of the most salient pedagogical writings that are relevant to the research problem (Chapter 3). Finally, I present a critical discussion of the main pedagogical approaches identified in Chapter 3 against the backdrop of current voice science (Chapter 4).

2. HISTORICAL CONTEXT: A BRIEF HISTORY OF THE TENOR VOICE

2.1. The "tenor" in medieval church music

The earliest advances towards virtuosic classical vocal technique took place in the context of church music. These advances were likely driven, at least in part, by the need for increased projection to fill the increasingly large ecclesiastical spaces of the late Middle Ages (Potter and Sorrell 2012, 74).

The origin of the term, "tenor", is unclear, except insofar as there is agreement that it derives from the Latin verb, *tenere* ("to hold"), and that it was first used in medieval ecclesiastical music (Henderson 1921, 59, Potter 2009, 4-5). Potter (2009, 4-5) identifies the term with the medieval *tenorista*, a specialist singer who held (hence *tenere*) the slow-moving lower line that formed the foundation of medieval polyphonic chant (Potter 2009, 5, 7).

It is unlikely that these early male singers made any concerted attempt to expand their ranges upwards. Early Christian liturgical music was unaccompanied, with the result that singers would simply choose a pitch for every piece that was comfortable for their voices (Haynes 1994, 41). Giuseppe Paolucci, writing on the art of counterpoint in 1765, mentions that as late as the end of the sixteenth century, before castrati were commonly employed, composers were constrained in their use of high notes in vocal music because no singers were reportedly able to sing them (Haynes 1994, 42).

2.1.1. Treatment of vocal registers in early music

It is not clear at what point the existence of vocal registers was first addressed in the course of vocal study, but we can infer that throughout the medieval period, no conscious attempts were made to blend or unite the vocal registers. For example, in the earliest known treatise on singing (c.1250), Jerome of Moravia defined three registers, namely chest, throat and head (the latter presumably referring to what we now call falsetto) but stated that these registers should be kept separate and pure. Jerome's views on the separation of the registers were reaffirmed as late as the fifteenth century by Conrad von Zabern in his treatise, *De modo bene cantandi* (published in 1474), where he specifically warned singers against attempting to make a uniform sound throughout their range (Potter and Sorrell 2012, 52). It is interesting to observe that Marchetto, a writer from around 1300, described a yodel-like vocal ornament which was performed by repeatedly passing from chest voice to falsetto on the same note (Henderson 1921, 28).

Keeping the registers separate would have had some utility in a world where women were not allowed to sing in church, as it enabled composers to utilise three distinct vocal colours for the high, middle and low voice parts (Potter and Sorrell 2012, 45). They were also able to expand the compass of their

compositions from two to three octaves (Henderson 1921, 136). Notwithstanding its evident utility, the employment of falsetto in Christian liturgical chant was apparently not uniform throughout Europe, as we see that St. Bernard (1090-1153) stipulated in his regulations of the chant at Citeaux: "It is necessary that men sing in a virile manner and not with voices shrill and artificial like the voices of women" (Henderson 1921, 43).

It appears that the dislike of the falsetto timbre became more prevalent as time went on; by the end of the sixteenth century Lodovico Zacconi (1555-1627), Kapellmeister at the court of Wilhelm, Duke of Bavaria until 1596, wrote in his *Prattica di musica* (published in 1592) of a general preference for the chest voice among music professionals, coupled with a dislike of the "shrill and penetrating" quality of the head voice (Stark 1999, 58-59). It was this general dislike of the falsetto timbre, coupled with the continued prohibition against women singing in church, which eventually led to the acceptance and ascendance of the castrato voice at the beginning of the seventeenth century (Celetti 1991, 108).

2.1.2. Male falsettists and castrati in early music

The desire of composers to employ a feminine tonal colour for the high voice in choral music could be addressed by various means. An obvious solution would be to use the treble voices of boys. However, their vocal usefulness was short-lived, firstly because of the long time it took for them to acquire the necessary musicianship to cope with the ever-increasing complexity of *a cappella* church music, and secondly because of the inevitable onset of the vocal mutation associated with puberty (Pleasants 1981, 37, Cathcart 2001, 51). Consequently, and despite the prevalent dislike of the falsetto timbre alluded to above, male falsettists had become a fixture in Christian liturgical music by the fifteenth century (Henderson 1921, 135-136). These falsetto singers were generally imported from Spain, where a more evolved and aesthetically pleasing form of falsetto singing was practised (Pleasants 1981, 38). It is believed that the superior technique of the Spanish *falsettisti* was absorbed from the Moorish invaders, as falsetto singing was practised and admired as an art in the near East from the eighth century (Giles 1994, 3).

Eviration was another practice that had a long history in the near East, and the employment of eunuch singers at the court of the East-Roman emperor at Constantinople and in the Eastern Christian Church can be traced back to as early as the fourth century (Duey 1951, 48).

Moorish rule was probably also the agency through which the practice of eviration spread to Spain, and it has been suggested that some of the early Spanish *falsettisti* may in fact have been castrati. This may well have been true in some cases, as there is evidence of castrati being employed at the Sistine Chapel and elsewhere in Europe from as early as the 1560s, well before the earliest "official" record of castrato employment in 1599, when two castrati were employed at the Sistine Chapel despite the strenuous

objections of the incumbent *falsettisti* (Pleasants 1981, 38, Potter and Sorrell 2012, 88). The *falsettisti* proved to be no match for their surgically altered rivals and were soon completely supplanted by them throughout Italy (Pleasants 1981, 50-51).

2.2. Seventeenth and eighteenth centuries: the birth of opera and the tenor-castrato connection

2.2.1. The Renaissance tenor as *primo uomo*

One of the most significant developments in vocal music during the 1590s was the emergence of opera as an art form when a group of musicians and poets in Florence, known as the Florentine Camerata, sought to revive the intoned style and structure of ancient Greek theatre. The resulting form of melodic declamation coalesced into operatic recitative, which formed the main means of storytelling in early operatic works (Celetti 1991, 16, Henderson 1921, 99, Potter and Sorrell 2012, 78).

It is during these early days of opera that the tenor voice, albeit with a vocal range which was limited to that of a modern baritone (Celetti 1991, 19), acquired something closer to its modern meaning, in the sense that the tenor became the main romantic protagonist in the early operas composed by members of the Florentine Camerata, and of the Roman and Venetian schools of opera (Potter 2009, 2009).

In keeping with the pragmatic demands of the music profession since medieval times, many early opera composers, such as Giulio Caccini and Jacopo Peri (both tenors), embodied an amalgamation of the roles of singer, composer and accompanist (Potter and Sorrell 2012, 63, 86, Potter 2009, 12). It was only natural, therefore, that the parts of the main romantic protagonists in these early operas would be written for the composers themselves, with Peri enjoying the distinction of giving one of the earliest-known operatic performances by a named tenor soloist (Potter 2009, 11). At the same time, a species of "gentleman amateur" also rose to stardom, the most famous being the tenor, Francesco Rasi, who appeared in practically all the operas by Peri, Caccini, Cavalieri, Monteverdi and Gagliano, before his career came to an abrupt end after a murder conviction in 1609 (Potter and Sorrell 2012, 80, Potter 2009, 15).

An important trend, established early in the Renaissance, was the progressive internationalisation of the Italian style and technique of singing, as singers like Rasi, and soprano Francesca Caccini started receiving engagements north of the Alps (Potter and Sorrell 2012, 80).

2.2.2. Treatment of vocal registers during the reign of the renaissance tenor

By the time that Caccini wrote his ground-breaking preface to *Le nuove musiche* (1602), the general understanding of the singing voice had coalesced into the recognition of two vocal registers, which

Caccini termed the "natural" (chest) voice and the *voce finta* (Caccini 1602/1970, 56). *Voce finta* (literally "feigned voice"), might have been the origin of the term, falsetto (literally "little false voice") which was adopted later (Nair 2003, 56). In line with the general dislike of the falsetto timbre alluded to above, Caccini (1602/1970, 56) advised singers in his preface to avoid any use of the *voce finta*, which he regarded as offensive to the ear, by choosing a key that would allow them to sing in their "full and natural" voice. As a result of such negative views regarding the falsetto timbre and its suitability to the new expressive style of operatic singing, early Renaissance writings on vocal pedagogy generally do not deal with falsetto technique (Stark 1999, 36).

The single register approach ordained by Caccini, together with the anathema of entering falsetto, evidently did not suit all voices, giving rise to complaints of "shrieking" and "shouting", which suggests that singers from this period sometimes resorted to register violation to sing the high notes in unmodified chest voice (Nair 2003, 56, Stark 1999, 59).

2.2.3. The rise of the castrato and decline of the tenor

Given that the first castrati had already been making their mark at the Sistine Chapel and elsewhere in the ecclesiastical sphere from around 1560 (see 2.1.2 above), they were poised to enter the new world of opera (Potter 2009, 18).

The resulting rise of the castrato was unstoppable, being fuelled by the Baroque fascination with fantasy, unusual vocal timbres, sexual ambiguity and androgyny. Operas from this period conjured fantastical realms populated by gods, heroes, villains and other mythological figures from the ancient world, to which the other-worldly timbre of the castrato voice was ideally suited (Celetti 1991, 2-9, Potter 2009, 17-18). The unique physical characteristics of the castrati, such as enlarged ribcages coupled with underdeveloped voice boxes which retained their flexible cartilaginous structure much longer than unmutilated singers, gave them extraordinary vocal powers which could not fail to impress audiences (Potter and Sorrell 2012, 87). One should also not underestimate an audience's fascination with high voices, which was likely as intense then as it is now.

Due to the ensuing dominance of the castrato in Italian opera, we see the tenor being relegated to peripheral character roles for the next two centuries (Potter 2009, 18-19).

French composers never fully embraced the castrato, with the result that the tenor fared better in France, where a species of high tenor, the *haute-contre*, flourished under composers such as Jean-Baptiste Lully (1632-1687) and Jean-Philippe Rameau (c.1683-1762) (Potter 2009, 22). Descriptions of the *haute-contre* (Potter 2009, 19-22, 24, Celetti 1991, 167) suggest that these high French tenors used a falsetto-

based technique similar to their later Italian counterpart, the *tenore di grazia*, who would eventually supplant the castrato.

The castrato also failed to conquer England fully, with the result that the English countertenor flourished there in the seventeenth and eighteenth centuries (Cathcart 2001, 52-53).

2.2.4. Treatment of vocal registers during the reign of the castrato

The essence of the castrato technique was the achievement of a smooth transition from chest to falsetto register and the "equalisation" of the chest and falsetto timbres. Although they still sang their high notes in falsetto (Potter 2007, 99), one can surmise that it would have been more akin to the developed falsetto of a modern female soprano or mezzo-soprano, as contemporary commentators spoke of chest voice production even in relation to the castrato's high notes (Celetti 1991, 113).

2.2.5. From the ashes of the castrato, the *tenore di grazia*

After defining the art of singing for much of the seventeenth and eighteenth centuries (Potter 2007, 99), the fate of the castrato was to vanish with the changing aesthetic and moral attitudes. One of the last appearances by a castrato in an operatic performance was in Venice in 1824, in Meyerbeer's early work, *Il crociato in Egitto*, which he wrote for the castrato, Giovanni-Battista Velluti (Pleasants 1981, 51). In London, the last known record of a performance by a castrato dates from 1844 (Hatzinger, et al. 2012, 2237). The castrati survived longer at the Sistine Chapel, the last of their line being Alessandro Moreschi (1858-1922), who is also the only castrato to have made audio recordings (Hatzinger, et al. 2012, 2237, Pleasants 1981, 51, Moreschi 1904a).

In place of the vanishing castrato, the tenor was destined to re-emerge, ironically as a product of the very same singing schools of the great castrati. In eighteenth-century Italy, singing teachers were generally castrati who had turned to teaching after successful singing careers, and pre-pubescent boys who displayed vocal talent would typically be apprenticed to such teachers (Potter 2007, 98-99). Potter and Sorrel (2012, 89) quote fascinating contemporary descriptions of life at the *conservatori* where these youths would have received their musical training, painting a picture of chaotic industriousness as young boys, crammed into every available space (even the dormitories and staircases), practised a gamut of instruments or wrote out their harmony exercises in the midst of the cacophony, the singers huddling together to keep warm and protect their voices against the perils of a chill.

Although pressure to perform castration continued into the early nineteenth century, not all boys apprenticed to a castrato teacher would suffer this fate. It is said that Rossini himself, not to mention

Gilbert-Louis Duprez who famously became the first tenor to take the high C in chest voice (see 2.3.2 below), narrowly avoided mutilation (Potter 2007, 100, 110, Potter 2009, 51).

The voice of a castrato teacher served as a surprisingly effective model for the training of young tenor voices, even when allowed to develop as nature intended. While singing as trebles, their voices were sufficiently similar to those of their castrati teachers that a great deal could be learned through imitation. Even after their voices had broken, the fledgling tenor voices remained sufficiently similar to that of the castrato, albeit now an octave lower, so that they continued to be treated no differently (Potter 2007, 99-100). This early tenor-castrato connection determined the nature of tenor technique for generations, as the tenors of this era were trained to develop their upper registers in much the same way as the castrati did. Thus, the castrato-trained tenor gained access to a falsetto-based upper extension of his voice which greatly expanded his range beyond that of the Renaissance tenor (Potter 2007, 100-103).

It is difficult to determine the vocal ranges of the earliest eighteenth-century tenors as composers would not necessarily notate the high notes, it being customary to entrust these to the singer's "ornamental discretion" (Potter 2009, 24). Composers would pragmatically confine their writing to conservative tessituras that they considered manageable for the duration of an evening's performance and by the end of the eighteenth century, "there was a substantial gap between the highest composed notes and the known ranges of many singers" (Potter 2009, 24). However, by the middle of the nineteenth century, these tenors, referred to variously as *tenori di grazia* and *contraltino* tenors, had become proficient at reaching heights that are stratospheric by today's standards. In response, composers gradually increased their notated tessituras, going as high as the famous F5 which Bellini wrote for the tenor, Giovanni Battista Rubini (1794-1854), in "Credeasi misera…" from *I puritani* (Potter 2007, 97).

Throughout this time, the *haute-contre* continued to flourish in France, producing a tradition that would eventually become intertwined with that of the *tenore di grazia*, as the Italian style of singing became internationalised (Potter 2009, 21, Pleasants 1981, 130, 164, 167).

2.2.6. Treatment of the registers during the reign of the *tenore di grazia*

This new species of castrato-trained tenor, for whom Handel, Mozart, Donizetti, Bellini and Rossini composed, preceded the advent of sound recording technology. As a result, we can at best use contemporary descriptions to make educated guesses about the type of sound which they produced. It is believed that the tenors from this period sang their high notes (from G4 upwards) in a type of developed or reinforced falsetto, or *falsettone* (literally "big falsetto"). Like their castrati teachers, these tenors would have learned how to achieve a seamless transition from chest voice into falsetto, and to produce their falsetto tones, described as "soprano-like without being effeminate" (Potter 2007, 107,

Regidor Arribas 2016, 1), with sufficient power to impress audiences and carry above an orchestra in the relatively large theatres of the time (Celetti 1991, 112-113, Potter 2009, 19-20).

John Braham, an English tenor who had trained with Rauzzini, a castrato teacher in Bath, was so famous for his smooth passaggio that *The Musical Quarterly* set up an experiment during which expert listeners were asked to determine where his register break was. Braham was reportedly able to transition from chest voice to falsetto on any note of his choosing between D4 and A4, and the transition was managed with such skill that the listeners participating in the experiment were unable to identify the transition point (Potter 2007, 101). Other contemporary descriptions make it clear, however, that not all tenors were equally successful at achieving a smooth transition (Potter 2007, 103).

2.3. Nineteenth century: the birth of the "modern tenor"

2.3.1. A new type of tenor emerges in Italy

In the early nineteenth century, a new, more powerful type of tenor started to emerge in Italy. By this time, the influence of castrato teaching was on the wane, as few of them were still living. This created an opportunity for tenors to explore new possibilities in their own voices. Contemporary commentators frequently commented on the fact that tenors were starting to raise the pitch at which they passed from chest to head voice. For example, in 1823, a review of a performance of Rossini's *Otello* by tenor Domenico Donzelli (1790-1873) mentions that he "attacks the high A in full chest voice without once resorting to falsetto" (Potter 2007, 106). This new type of singing resulted in an early casualty when tenor Americo Sbigoli burst a blood vessel and died on stage while trying to emulate Donzelli (Potter 2009, 50). Notwithstanding such health risks, the more robust sound took hold and was embraced by composers such as Gaetano Donizetti (1797-1848), who appreciated its increased dramatic power (Potter 2009, 55, Regidor Arribas 2016, 1-2).

2.3.2. Gilbert-Louis Duprez and the *ut de poitrine*

In 1828, Gilbert-Louis Duprez, an obscure tenor who had only achieved marginal success in Paris (Pleasants 1981, 165), decided to travel to Italy in the hopes of improving his career prospects by learning the new, more robust Italian singing technique (Potter 2009, 51). There, he was mentored by tenor Donzelli, mentioned above (Potter 2009, 52), and sufficiently impressed Donizetti for the latter to write the role of Edgardo in *Lucia di Lammermoor* for him (Pleasants 1981, 166).

Duprez's success in Italy continued and, in 1831, he reportedly sang a high C (C5) in full chest voice in a performance of the role of Arnoldo at the Italian première of Rossini's *Guglielmo Tell* in Lucca (Potter 2007, 106). On the strength of his growing reputation in Italy, Duprez was invited back to Paris

in 1836, to take up an engagement as lead tenor at *L'Opéra de Paris*, a position he was to share with the famed Adolphe Nourrit, variously described as an old-school *tenore di grazia* or *haute-contre* (Celetti 1991, 167), who was then at the height of his powers (Potter 2009, 48).

What followed has entered operatic lore as nothing less than the "origin-myth" of the modern tenor voice (Bloch 2007, 12). At a performance of the French version of *Guillaume Tell* at the *Opéra*, Duprez again took the high Cs in Arnold's aria in chest voice, causing a sensation with the Paris audience. Rossini's response to this feat was reportedly less enthusiastic; he is said to have described it as the sound of "a capon squawking as its throat is cut" (Potter 2007, 106, Pleasants 1981, 167). Rossini is also said to have predicted the early demise of Duprez's singing career due to his effortful method of voice production (Herbert-Caesari 1950, 178).

Nourrit, intimidated by his young rival, immediately resigned from the *Opéra* and went to Italy to learn this new vocal technique from none other than Donizetti himself (Pleasants 1981, 164, Potter 2009, 49). The popularised version of the tale[11] ends with Nourrit being utterly disappointed by the results of his endeavours, causing him to end his life in despair in 1839, by jumping from the window of his apartment in Naples (Pleasants 1981, 162-164).

Duprez's feat sparked a fierce pedagogical debate regarding the nature of the tenor's upper register. This coincided with the advent of an increasingly scientific approach to voice research, with Duprez himself forming the subject of a scientific paper, entitled *Mémoire sur une nouvelle espèce de voix chantée*, by Paul Diday and Joseph Pétrequin, published on 16 May 1840 in the *Gazettemédicale de Paris*, a weekly newspaper aimed at Paris's medical professionals. In this essay, Diday and Pétrequin expressed the view that Duprez's method of voice production, which they termed *voix sombrée* ("darkened voice"), was forced, unnatural and dangerous to the singer, and they confidently predicted that "for rigorous physiological reasons" this method of voice production would imminently die out (Bloch 2007, 15).

Duprez did indeed start developing vocal trouble while still relatively young and retired from singing at the age of 43 (Pleasants 1981, 167-169). However, contrary to Diday and Pétrequin's prediction, Duprez's method of darkened, low larynx singing with chested high notes did not disappear, as the younger generation of tenors eagerly continued pushing the boundaries of chest voice production.

[11] The Duprez-Nourrit incident has undoubtedly been mythologised and embellished. For example, it is documented that Nourrit's suicide was brought on more by his deteriorating health than his inability to acquire the chested high C (Bloch 2007, 12).

2.4. The twentieth and twenty-first centuries: no turning back

For a time, the old-school technique continued to co-exist with the new "Romantic" technique, obliging composers to adapt their compositional style to suit the vocality of the singers for whom they composed (Regidor Arribas 2016, 3). However, the appeal and success of the modern tenor with his "chested" high notes continued to grow unabated, so that it quickly became established as a new orthodoxy by the early twentieth century. Today, the term *tenore di grazia* is applied even to tenors such as Alfredo Kraus, Juan Diego Flórez, Colin Lee and Lawrence Brownlee who, while being lighter-voiced, are able to maintain the same high tessituras as their eighteenth-century counterparts without resorting to a falsetto-based production.

Some prominent pedagogues, such as Edgar Herbert-Caesari (1950, 178, 1936, xix), have lamented the demise of the falsetto-based technique of singing in the upper register, arguing that the "old-school" vocal technique was aesthetically superior. A typical complaint is the lack of dynamic control of the modern tenor in his high register, and in particular his inability to perform *messe di voce* and controlled *diminuendi* (1950, 178), as well as a general abandonment of "the melodious delicacy of *belcantismo* in favour of coarseness and shouting" (Regidor Arribas 2016, 3).

It is perhaps in response to these criticisms that a minority of successful twentieth-century tenors, such as Luigi Alva, William Matteuzzi and Werner Hollweg, chose to adhere to the old-school falsetto-based technique. However, these appear to be no more than exceptions that prove the rule. The dominance of the modern tenor sound is unassailable, and the attainment of a chested high C represents a holy grail for nearly all aspiring tenors of today.

3. THE TENOR'S LEGITIMATE HEAD VOICE: HISTORICAL AND MODERN PEDAGOGICAL APPROACHES

3.1. Introduction

The birth of the modern tenor in the early nineteenth century represents a watershed moment in the history of vocal pedagogy. The earlier authorities uniformly accept it as axiomatic that an expanded vocal range is synonymous with multi-register singing, which requires a smoothing-over of the register transition (*passaggio*). Subsequent writings introduce new concepts, such as *voix mixte* (mixed voice) and expanded ideas around register-blending or -unification of voice source mechanisms in an attempt to make sense of the changed tenor vocality. In the twentieth century, advances in voice science have given rise to further concepts such as TA-CT dominance, which have reverberated through the pedagogical literature.

3.2. Seventeenth and eighteenth centuries: pedagogical writings in the time of the castrato and *tenore di grazia*/*contraltino* tenor

Opinioni de'cantori antichi e moderni, written by the castrato Pier Francesco Tosi (c.1653-1732) and published in Bologna in 1723, is considered to be the first comprehensive treatise on vocal technique. This treatise was enormously influential throughout Europe and was subsequently translated into English by John Ernest Galliard in 1743 and into German by Johann Friedrich Agricola (1757/1995), who added extensive footnotes with his own observations.

Tosi inherited the two-register model – chest and head[12] voice – expounded by Caccini (see 2.2.2 above). However, in contrast to Caccini, Tosi insisted on the use of the head register as a means of expanding the singer's range beyond the "narrow compass of a few notes". The different timbral qualities of the two registers inevitably presented an aesthetic problem, and Tosi, therefore, also insisted on the need for students to unite or join the registers in a way that would render the transition imperceptible. Disappointingly, Tosi's treatise contains no advice on the training through which this is achieved, apart from stating that the student should "leave no means untried so as to unite the feigned and the natural voice that they may not be distinguished" (1743/1987, 6).

[12] Tosi identifies three registers, namely chest, head and falsetto. It is clear from his description, however, that he uses the term, falsetto, to designate the few semitones at the upper extreme of a voice, which are unusable due to their forced nature. Agricola (1757/1995, 75) corrects the potential confusion of the Italian nomenclature used by Tosi, by pointing out that Tosi's "head voice" is in fact the equivalent of falsetto as used in the eighteenth century.

Agricola (1757/1995, 68-80), on the other hand, expounds at length on the nature and physiological differences between the registers in his notes to Tosi's *Opinioni*, and does mention one exercise for the so-called "unification" of the registers. With this exercise, the student would be asked to sing the transition notes around the register break in both voices, and specifically to sing these notes in falsetto in descending passages, while the same notes would be sung in chest voice in ascending passages (Agricola 1757/1995, 77). The purpose of this exercise, according to Agricola, was to equalise the strength and timbre of the lowest notes of the falsetto register and the highest notes of the chest register (Agricola 1757/1995, 76).

A much more sophisticated treatise on singing technique, entitled *Pensieri e riflessioni pratiche sopra il canto figurato*, was published in 1774 by another castrato, Giambattista Mancini (1714-1800). Like Tosi before him, Mancini states: "The great art of the singer consists in acquiring the ability to render imperceptible to the ear, the passing from the one register to the other. In other words, to unite the two, so as to have perfect quality of voice throughout the whole range, each tone being on a level with your best and purest tone" (Mancini 1774/1912, 59).

Mancini is more detailed in his instructions on how to achieve this: The first step is for the student to determine for himself where the transition between his chest and head registers are, as this is not necessarily the same in all voices (Mancini 1774/1912, 108). Next, the student embarks on the study of equalising the power of the two registers by holding back the tones of the stronger register (which may be either the chest or head voice, depending on the individual), and incrementally adding greater force to the tones of the weaker register (Mancini 1774/1912, 109-110). As the weaker register gains in strength, the student may periodically test his progress by singing the tones of the stronger register with the usual strength to compare it with the strength of the weaker. Once the two registers are of equal strength, Mancini says that the student "will be glad for the achieved success of having the two registers blended" (Mancini 1774/1912, 110).

Mancini does not explicitly prescribe any exercises for attaining a smooth transition across the register break. In fact, the previous quote seems to imply that a smooth transition between the registers would be an automatic result of the successful equalisation of the strength of the registers as described above. On the other hand, his treatment of the study of *portamento* and *messa di voce*[13] appears to suggest that these exercises might play a role in register unification (Austin 2007, 61). *Portamento di voce* is prescribed by Mancini as the next step following the successful equalisation of the registers, and is

[13] Literally, "placing of the voice". This refers to a vocal exercise performed on a single pitch, which the singer starts piano with a slow and gradual crescendo to forte, followed by a symmetric diminuendo back to the starting dynamic. For a fuller description, see the relevant quoted passage from García's *Traité Complet* in Chapter 3.3.3.

defined by him as "the gliding of the voice [and a] blending of the voice from one tone to another, with perfect proportion and union" (Mancini 1774/1912, 111). *Messa di voce*, which is recommended even by current pedagogues as a means of register unification (McCoy 2003, 405-406), is mentioned in the same context, where Mancini states that the "industrious student" who has attained a degree of skill in *portamento* "will find at the end surprising ease in the perfection of the 'Messa di Voce'" (Mancini 1774/1912, 113).

It is interesting to note that Mancini mentions the rare phenomenon of naturally gifted singers who were able to sing in chest voice throughout their range (Mancini 1774/1912, 58, 108). Stark (1999, 61) points out the ambiguity in this statement, as it is not clear whether such singers were blessed with chest and falsetto registers that naturally sounded the same, or whether they had an innate skill which enabled them to extend their chest voices upwards.

The pedagogical principles of the Tosi-Agricola-Mancini lineage were promoted in Germany by the prolific singer-composer, Johann Adam Hiller (1728 – 1804), in his books, entitled *Anweisung zum musikalisch-richtigen Gesange* (published in 1774) and *Anweisung zum musikalisch-zierlichen Gesange* (published in 1780). Hiller's purpose with these two volumes was to address what he regarded as the "substandard singing in Germany" as compared to the "excellence of Italian standards of singing and teaching" (Beicken 2004, 17), and he specifically addressed the need for singers to use their falsetto register to increase their range and to achieve a smooth, unnoticeable transition between the chest and falsetto registers (Hiller 1774, 10-11). However, he does not provide any detail on how to achieve this.

The clear thread running through the writings of Tosi, Agricola, Mancini and Hiller indicate that, despite stylistic changes in singing, technique remained relatively unchanged until the beginning of the nineteenth centuries (Potter and Sorrell 2012, 98). It seems clear that the castrati generally sang their high notes in a developed or reinforced falsetto register, and their main achievement was their attainment of a smooth transition between the registers. Celetti's observation, referred to in 2.2.4 above, that contemporary commentators spoke of chest voice production in relation to the castrato's high notes might indicate that the developed falsetto register of the castrato bore some similarities to the upper register of the modern soprano and mezzo-soprano. Be that as it may, the one extant recording of castrato singing, in particular the rendition by Moreschi (1904b) of Bach-Gounod's *Ave Maria*, shows evident register transitions with a clear falsetto tone colour in the high notes.

As stated above, the eighteenth-century *tenore di grazia/contraltino* tenor relied on a falsetto-based technique for their high register, as taught by their castrato teachers. This early tenor-castrato connection not only determined the nature of tenor technique at the time, but also ensured the preservation and transmission of the register-blending ideas of the castrati to later generations long after their

disappearance (Potter 2007, 100). Potter (2007, 109) believes that the modern countertenor represents a living model of the sound which the *tenore di grazia* would have produced in his upper register. Although we are unable to verify this with reference to sound recordings, a biographical detail shared by Edgar Herbert-Caesari (1950, 178) lends credence to Potter's theory. Herbert-Caesari studied in Rome with a *contraltino* tenor of the Sistine Chapel, named Riccardo Daviesi, who still adhered to the Old Italian School of singing. Daviesi apparently used his chest voice only up to F4, after which he used a tone referred to as "a mixture of pharyngeal and falsetto". According to Herbert-Caesari's description of this "pharyngeal-falsetto" mixture, it bore a remarkable similarity to the tone of a mezzo-soprano or contralto (and hence, perhaps a modern countertenor), so much so that "often you cannot distinguish the one from the other".

Stark (1999, 67) refers to several post-Mancini authors who, according to him, muddied the waters somewhat by proposing a three-register model, variously termed *voix de poitrine* (chest), *voix de gozier* (throat) and *voix de tête* (head), or "low", "medium" and "high" voice. While these views might appear to disturb the neat two-register model espoused by Tosi and Mancini, one could argue that the second register (*voix de gozier* or medium voice) is implied in their views, as it could refer to the area of transition (the *passaggio*) between the registers, where the chest voice and falsetto overlap, and where the singer needs to make certain adjustments to achieve a smooth transition.

3.3. Nineteenth century: significant pedagogical writings after the "birth of the modern tenor"

While tenor lore portrays the Duprez-incident as nothing short of a revolution, the traditional methods of register-blending or -unification proved to be robust and largely resistant to being overturned by this revolution. Pedagogues from the second half of the twentieth century were certainly cognisant of the changed vocality of the tenor voice and they clearly entertained the notion that the tenor is capable of singing his entire upper range in chest voice. However, the following analysis reveals some cognitive dissonance among pedagogues in this regard, as even the legendary Duprez himself appears to be unable to accept that tenors can and should use their chest voice throughout their range. So, instead of a revolution, we see an evolution of pedagogical ideas with the emergence of "mixed voice" as the purported mechanism for the tenor's upper register, and the introduction of a more mechanistic approach to the blending/unification of voice source mechanisms.

3.3.1. Gilbert-Louis Duprez (1806-1896)

Given that Gilbert-Louis Duprez's name is synonymous with the birth of the modern tenor, one might hope that he left behind some clues regarding his own "revolutionary technique", and the way in which tenor technique was changing during his time. Indeed, after his retirement from singing, Duprez became

a respected teacher – and a rather less successful composer (Pleasants 1981, 170). However, his two published works, a book on singing technique, entitled *L'Art du Chant* (1846), and a memoir, entitled *Souvenirs d'un Chanteur* (1880), offer disappointingly few clues as to how he achieved his feat of the chested high C.

In *L'Art du Chant*, Duprez (1846, 4) states at the outset that he does not consider it necessary to deal with the physiology of the human voice; "[j]ust as a poet does not need to know the physiology of the brain to write verses, so knowledge of the anatomy of the vocal organs is useless for singing." In line with this sentiment, his treatment of voice types and the vocal registers is brief, indicating that the high tenor's chest voice ranges from E3 to F4, of which two notes overlap with the "mixed register", which ranges from D4 to B♭4, while B4 to D5 are indicated as falsetto tones. In a brief explanatory note, Duprez states that, very rarely, a high tenor may be able to sing all of these notes in chest voice. According to him, these rare voices sometimes came from the southern regions and were formerly known as *haute-contres*. He continues to state that the *haute-contre* is a highly-prized voice that should combine "the power of a man's voice with all the sweetness and charm of a woman's voice" between the notes of C4 and C5 (Duprez 1846, 5). Presumably, this comparison to the qualities of female voices did not apply to the rare *haute-contre* whom Duprez mentioned as having the ability to sing his upper register in chest voice.

Duprez (1846, 5) also briefly mentions what he regards as the most-common male voice type, namely the "short" tenor (*ténor taille*), whose chest voice only reaches as high as D4, with an additional fourth consisting of mixed voice up to G4, and a falsetto extension to B♭4.

After this brief introduction to voice types, Duprez (1846, 6) continues with, similarly brief, preliminary advice for the execution of the series of practical lessons which form the bulk of the book. This includes an instruction to commence vocalisation on the vowel [ɑ], which he says must be pronounced as in "*âme*", and not "*ami*". He clarifies that this slight modification of the vowel is referred to in France as "darkening the tones" ("*sombrer les sons*"), but adds that this term is incorrect, being unknown in Italy, "where they have no other way of producing sound".

In two further allusions to registration events, Duprez (1846, 6, 64) writes as follows:

> There is no student who does not perceive a change of timbre in his voice when he arrives at certain notes. The transition must take place with the utmost caution; the equality of the voice depends on this. For example, the soprano's chest voice can reach up to A, B, C of the medium [register]; but then B, C and D generally have a much weaker and a disparate timbre. One must avoid this inconvenience as far as possible by gradually softening the two notes which precede those on which the change occurs, rounding and reinforcing [literally 'forcing'] the two notes which follow. But I urge

> students to push the limits of their chest voice as far as possible, because laziness or fear of the effort often cause them to lose this powerful resource.[a]

And again:

> [I]t is necessary to extend the limits of the chest voice and the intermediate or mixed voice as far as possible in order to obtain more strength and brilliance and to avoid disparities in the change of the registers.[b]

The first practical lesson which Duprez (1846, 6-7) includes in *L'Art du Chant* covers *messa di voce* and *portamento*, both of which are often cited as a means of uniting the registers (McCoy 2003, 405-406, Garcia 1847a/1985, 60-61, Austin 2007, 61). However, he does not explicitly ascribe this function to these two exercises.

Turning to Duprez's memoir, one is equally disappointed in the search for information on how he attained the chested high C. Although it is known that Duprez was mentored by the Italian tenor, Domenico Donzelli (see 2.3.2), he fails to credit the latter, and suggests that he already knew all there was to know about singing when he arrived in Italy in 1828; this despite recounting that he was advised, at his first audition, to take some lessons to perfect his technique (Duprez 1880, 18).

The most direct insight which Duprez (1880, 75-76) gives regarding his attainment of his chested high C, is found in the following passage:

> 'Follow me, warrior' ended with a note that I had never tried to reach; I, yesterday [still] a *tenorino*, barely having gained some understanding of dramatic performance practice in a single *opera seria*; the hair on my head stood on end! I immediately understood: these masculine tones, these sublime cries, rendered with mediocre means, would be a failed, and hence ridiculous, effect. In order to rise to the height of this energetic creation, it would require the concentration of the entire will, and moral and physical forces of the one who would be its interpreter...
>
> 'Ah! Upon my word', I exclaimed in the end, I may explode; but I will get there!
>
> This is how I found the *ut de poitrine* that brought me so much success in Paris, perhaps too much; for, what is a sound ultimately, if not a means of expressing a thought? What is a note, without the feeling that colours and animates it?[c]

The picture of Duprez that emerges from the above is a far cry from the mythologised version set out in 2.3.2 above. Far from embodying a revolution in tenor technique that would enable future tenor generations to sing their entire upper register, including C5, in chest voice, he continued to subscribe to the then orthodox view that an expanded tenor range was synonymous with multi-register voice production, which required a blending or unification of the registers. It is interesting, nevertheless, to note that Duprez referred to the tenor's upper register as *voix mixte*, instead of falsetto, as it indicates

not only that the concept of a transitional voice region, consisting of a mixture of chest voice and falsetto, was gaining ground at the time, but this notion was also being used to explain the newly discovered tenor vocality.

Regarding his own legendary feat in producing a chested high C, it appears that this was nothing more than a highly charged emotional cry, which would be inappropriate, not to mention unsustainable, in most lyric singing. Support for this view is found in the published proceedings of the presentation which García (1841/1847a, 11, 1847a/1985, 9) gave to the *Académie des Sciences* in 1840, where he includes Duprez's high C in a list of examples of *voix blanche* ("white voice"), and not *voix sombrée* as one would expect.

Finally, we know from other sources, such as Diday and Pétrequin's *Mémoire* referred to in 2.3.2, as well as Garaudé (see 3.3.2), that Duprez deserves credit for being the first to introduce *voix sombrée*, which was increasingly being practised in Italy at that time, to France upon his return from Italy in 1837. *Voix sombrée* appears to be a term that was coined by Diday and Pétrequin to contrast it with the *voix blanche* of the old style. According to them, it was achieved "by a lowering of the larynx, which was visible as a forward-tilted head and a lowered Adam's apple" (Bloch 2007, 14). Up to this point, there had been scientific consensus that the larynx should visibly rise for high notes (Bloch 2007, 16).

Based on the novelty of low-larynx singing and the associated *voix sombrée* in the 1830s (to which one could add Diday and Pétrequin's opposition to the practice), Potter (1998, 53) makes the reasonable assumption that earlier singers would generally have employed a relatively high larynx position, perhaps closer to that of normal speech height. The significance of Duprez's contribution might simply be that his introduction of this technique to France paved the way for the continued evolution of tenor technique, which would eventually lead to a new orthodoxy by the end of the nineteenth century, namely the maintenance of a permanent low-larynx position, coupled with the anathema of making any use of the falsetto timbre (Bloch 2007, 16-18).

Perhaps Duprez did in fact learn something about singing during his sojourn in Italy, despite his protestations to the contrary.

3.3.2. The official voice manual of the Paris Conservatoire

After the founding of the *Conservatoire Nationale de Musique* (the Paris Conservatoire) in 1795, a committee, whose members included the composers, Luigi Cherubini (1760-1842) and Fromental Halévy (1799-1862) (Garaudé 1854, 3), was formed to oversee the production of an official voice teaching manual for the Paris Conservatoire. The result was the *Méthode du Chant du Conservatoire de Musique*, authored by the Italian voice teacher, Bernardo Mengozzi (1758-1800), which was

published posthumously in 1803 (Sell 2005, 19). It was subsequently edited and expanded by Alexis de Garaudé (1779 - 1852), who was credited as the author of the second edition that was published in 1854.

In the 2nd edition of the *Méthode*, Garaudé (1854, 8, 16) adheres to the two-register model for male voices, which he identifies with the historical terms, "chest voice" and "head voice or falsetto", the latter two terms being used synonymously. Touching on the physiological basis of the registers, he mentions simply that chest voice is produced by the action of the larynx, before continuing with the head/falsetto register, where he displays a startling lack of physiological understanding, even for the time. According to Garaudé, this register is produced by the vibration of a secondary "pharyngeal glottis", which is formed through the raising of the soft palate and constriction of the pharynx that occurs once the limits of the chest voice are reached.

In a footnote, Garaudé (1854, 8) mentions, in an apparent reference to Gilbert-Louis Duprez, that "a new kind of voice, called *sombrée*, was imported to our operatic scene a few years ago by a famous singer". He continues to say that singers with "excellent lungs" can use this type of singing to increase intensity and impart greater energy to dramatic phrases. Garaudé warns, however, that young tenors risk losing their voices if they practise this type of singing "to exhaustion" in an attempt to gain "the appearance of a large voice that nature has denied".

Dealing specifically with the registers in the tenor voice, Garaudé (1854, 16-17) writes as follows:

> This voice has 2 registers: that of the chest and that of the head. To pass easily from one to the other, it is necessary to soften the last sound of the chest voice, and to reinforce the first sound of the head voice, which is weaker by its nature.
>
> Tenor voices are divided into two categories. The 1st tenor, which was formerly called *haute-contre*, sometimes reaches [B4] and [C5] in chest voice, not counting four tones [D5, E5, F5 and G5] in head voice. [D3] and [E3] are almost non-existent in this voice. The chest voice of the 2nd tenor, on the other hand, starts on these two notes, extending to [G4], with an additional few notes in head voice.
>
> In tenor voices, the skilful use of head tones has an infinite charm. One must endeavour to give them equality, [illegible], and purity, and to unite them imperceptibly with the chest voice.
>
> To gain the appearance of extending the chest voice upwards by a note or two, and to better unite the chest and head voice, tenors often use a feigned [literally "fake"] vocal quality, called *voix mixte*, in which one register participates a little in the other. This is done on the last note of the chest voice and can usually extend several semitones beyond the limits of the said register. To fully understand what this *voix mixte* is, one must hear it from a teacher.
>
> An intelligent tenor can make the most of this resource in order to sing certain phrases without changing register, or to avoid any type of hard register transition.[d]

It is clear from the above quote that, at the time of publication of the 2nd edition of Garaudé's *Méthode* in 1854, the official teaching method at the Paris Conservatoire relied on essentially the same register-blending approach espoused by the castrati teachers of the previous century, with a significant difference, however, namely the use of *voix mixte* as a means of attaining a smooth register transition and gaining the appearance of an extended chest voice. At this point, it would appear that the "Duprez revolution" was little more than a footnote in tenor history.

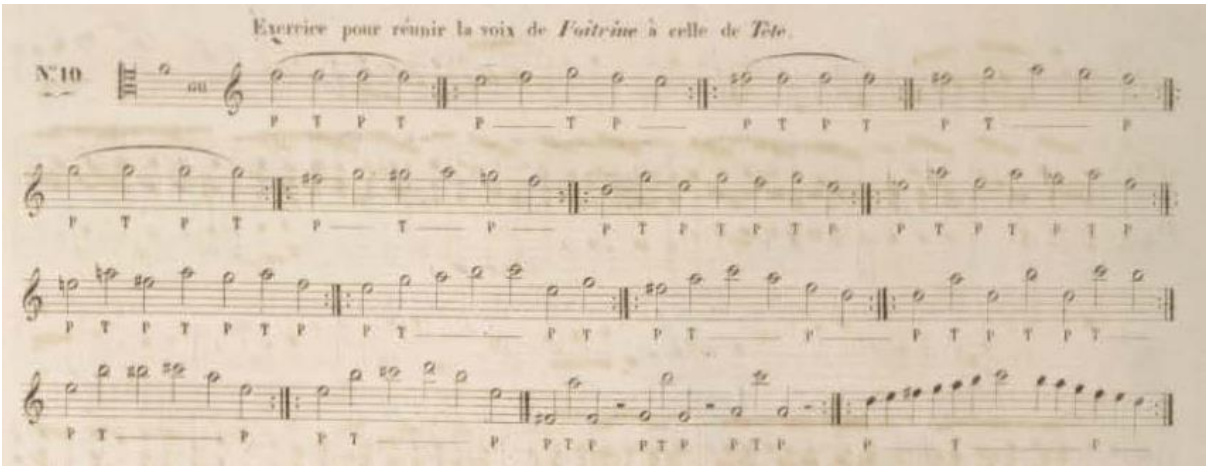

Figure 13: Exercise, entitled "Exercise for uniting the Chest voice with that of the Head", prescribed by Garaudé (1854, 16) in *Méthode du Chant du Conservatoire de Musique*. The notes marked "P", for *poitrine*, are to be emitted in chest voice, while the notes marked "T", for *tête*, correspond to head voice tones.

That said, the *Méthode* represents a notable innovation compared to the earlier pedagogical works surveyed, insofar as it contains the earliest published notation of an exercise that may have served as a model for the mechanistic exercises for the unification of voice source mechanisms that would become the hallmark of García's teaching (see 3.3.3). Unfortunately, Garaudé (1854, 16) did not provide any detailed instructions regarding the performance of these exercises, but it is clear from the notation (see Figure 13) that the student was required to alternate repeatedly between chest voice and falsetto on various intervals in the area of transition between the registers.

3.3.3. Manuel García (1805-1906)

Manuel García *fils* – not to be confused with his almost equally famous father, Manuel García *père* (1775-1832) – was the preeminent authority on vocal pedagogy of the nineteenth century. His influence can hardly be overstated, being clearly visible in the large number of nineteenth-century pedagogical writings that were modelled on García's work. Judging by the pervasive references to his work in current literature, his contributions remain relevant to this day. García's stature was due not only to his long teaching career in Italy, France and England, which spanned more than seventy years (from the early 1830s to his death in 1906), but also because he is regarded as the founding father of vocal

physiology, laryngoscopy and modern vocal pedagogy (Bloch 2007, 17). Part I of his *Traité Complet de l'Art du Chant* was first published in 1840, followed by Part II in 1847. This work subsequently went through eleven editions, with translations into German, Italian, Spanish and English. It remains a standard reference for singers, teachers and voice scientists alike.

García embraced the new form of robust tenor voice production in the upper register, as exemplified by Duprez after his triumphant return to Paris in 1837, and claimed to have taught *voix sombrée* (which he preferred to call *timbre sombre*) since 1832, when he first heard it in Italy (Potter 1998, 55).

He was clearly also aware of the pedagogical writings and register classifications of authorities who preceded him, which included those of Tosi, Mancini, and Agricola, as well as his mentors at the Paris Conservatoire, Mengozzi and Garaudé (Garcia 1847a/1985, 1, Stark 1999, 67-68). However, his treatment of the registers differs both in substance and nomenclature, starting with the following definition of the vocal registers which García (1847a/1985, 6) proposed in 1840:

> By the word register, we mean a series of consecutive and homogeneous sounds ranging from low to high, produced through the action of the same mechanical principle, and whose nature is essentially different from another series of equally consecutive and homogeneous sounds, produced by another mechanical principle. All the sounds belonging to the same register are, consequently, of the same nature, whatever else the modifications of timbre or force that one applies to them.[e]

This definition has largely stood the test of time, and its similarity to definitions used by current voice scientists is frequently noted (Zemlin 1968, 191-192, Potter 1998, 55, Hollien, Brown and Weiss 1999, 17, McCoy 2012, 143). The insight evident in García's definition is all the more remarkable considering that he formulated it more than a decade before he started making his own laryngoscopic observations in 1854 (Potter 1998, 55, Stark 1999, 5, Austin 2005, 241, M. Castellengo 2005, 167). García had obtained much of his knowledge of laryngeal physiology during his studies at a military hospital in the early 1930s (Potter 1998, 55, Sell 2005, 22), but he clearly also owed a debt to the work of contemporary physiologists, in particular the German, Johannes Peter Müller (1801-1858), whom García acknowledges in his *Traité Complet* (Garcia 1847a/1985, 12, 60).

With the above definition, García became the first to identify vocal registers with laryngeal events ("mechanical principle"[14]) that were separate and independent from resonance phenomena ("timbre")

[14] In the English edition of Garcia's *Traité Complet de l'Art du Chant*, entitled *Garcia's Treatise on the Art of Singing* (Garcia 1924, 4), *principe mécanique* is mistranslated as "mechanism", which obscures the more nuanced meaning of the term he actually used, namely "mechanical principle". However, elsewhere in his *Traité Complet*, Garcia (1847b/1985, 58) uses the term "mechanism" without qualification where he reasons that it is impossible to produce a mixture of chest voice and falsetto on any given note.

produced in the vocal tract. This conceptual separation between the voice source mechanism and modifying vocal tract resonance amounts to an early statement of linear source-filter theory (see Glossary definition), which would become the mainstay of scientific voice research for much of the twentieth century.

García's definition of the registers is also notable for its encapsulation of the perceptual qualities of the registers ("homogeneous sounds"), which are identifiable despite any modifications in timbre originating from vocal tract resonance, as well as the correlation between register and pitch ("series of consecutive tones").

Based on his definition of the registers, García (1847a/1985, 11-14) identified four vocal registers, namely *contre-basse* (the equivalent of what is now called "pulse register" or "vocal fry"), chest voice, falsetto-head and *voix inspiratoire* ("inspiratory voice"). He clarified that the last-mentioned has no function in singing, while the first-mentioned is only used by the *basso profundo*, with the result that chest voice and falsetto-head are the principal registers used by male and female singers (Garcia 1847a/1985, 7-8, 14).

Much has been made of the confusion that was caused by the fact that García placed head voice, the earlier term for falsetto used by the eighteenth-century authorities (see 3.2), above falsetto, thereby creating the impression that he viewed falsetto as an intermediate register (Stark 1999, 68). However, it is clear from a careful perusal of his work that García (1841/1847a, 4, 1847a/1985, 11) consistently maintained, on the basis of his experimental observations that found no break between the falsetto and head registers, that these were in fact two parts of the same register, albeit with sufficiently different timbres so that separate names were merited (Stark 1999, 69).[15]

In another departure from the prevailing views of the time, García (1847a/1985, 58) strongly opposed the notion of *voix mixte* or *voce di mezzo petto* ("half-chest voices") as a hybrid register partaking of both the chest voice and falsetto, maintaining that the vocal organ "is placed in completely different and irreconcilable conditions, depending on whether [the note] is produced with the chest or falsetto voice mechanism". Continuing in this vein, he states in various parts of the *Traité Complet* that the tenor's upper register between F4 and C5, which was commonly referred to as *voix mixte* at the time, is in fact produced in chest voice with *timbre sombre* (Garcia 1847a/1985, 9, 24, 58). According to García

[15] Recent research contradicts García's experimental observations in this regard, in that a clear register break with a characteristic discontinuity and frequency jump has been shown to exist between the female head (equivalent of García's falsetto) and whistle (equivalent of García's head) registers, leading to the identification of M2 (falsetto) and M3 (whistle) as distinct laryngeal mechanisms (Roubeau, Henrich and Castellengo 2008, 429-30).

(1847a/1985, 24), his contemporaries lacked appreciation of the "virile and dark vigour" of this form of chest voice production in the upper register.

García (1847b/1985, 58, 1894/1982, 17) gave F4 as the starting note of this upper extension of the tenor voice that can be sung in chest voice with darkened timbre, but was less consistent in his location of the highest note that could be sung with this technique, variously giving it as A4 (Garcia 1847a/1985, 23), B♭4, specifically for the *haute-contre* (Garcia 1847a/1985, 22), B4 (Garcia 1847a/1985, 22), C5 (Garcia 1847a/1985, 58) and D5 (Garcia 1847b/1985, 58).

Curiously, the 1847 edition of his *Traité Complet* (Garcia 1847a/1985, 11-14) contains extensive speculation, on the basis of his observation in Paris of *Baskirs*, who practised a form of overtone singing, that the falsetto was produced by the ventricular folds (false vocal cords), which he believed made it possible to simultaneously phonate at two different pitches, one note being produced in chest voice through the action of the vocal folds, and the other in falsetto through the action of the ventricular folds. In the course of these speculations, García rejected the views of the German physiologist, Johannes Peter Müller, that the registers are distinguished by the fact that only the ligamentous edges of the vocal folds vibrate in falsetto, while the vocal folds vibrate through a greater depth in chest voice. According to García (1847a/1985, 12), the isolated vibration of the ligamentous edges observed by Müller was not typical of falsetto, but in fact corresponded to the slender tones produced in the upper part of the chest voice. However, by the time of his presentation to the Royal Society of London in 1855, García (1855, 401-403) had accepted the physiological explanation proposed by Müller. Müller's observations regarding the vibrational difference between chest voice and falsetto, as subsequently accepted by García, have largely been confirmed by modern science (see Glossary definitions and the discussion in Chapter 4).

Despite García's scientific perspicacity, his views on the registers and the development of the tenor's upper register are characterised by a degree of ambiguity. For example, after being at pains to establish that the tenor's upper register is simply an extended chest voice, as described above, García (1847a/1985, 27) instructs tenors to use the falsetto register between G4 and C5. He also formulates what appears to be a type of passaggio theory for attaining a smooth register transition, where he states that tenors should gradually start rounding ("arondir") the notes between B3/C4 and F♯4, before transitioning into falsetto.

To complicate matters further, we find the practice of register-unification to be an important thread that runs through García's writings. Specifically addressing the tenor voice in a section of the *Traité Complet*, García (1847a/1985, 22) states: "For tenors, more so than baritones, the falsetto united with the chest register is a happy and natural resource". Further on in this work, García (1847a/1985, 27-29)

prescribes a series of exercises for the unification of the chest and falsetto registers, which is to be performed by all voices, including tenors. He warns, at the outset, that register-unification is only achieved through long, arduous practice. The relevant exercises entail the following: on the pitches of D4 to F#4, one should repeatedly, and with increasing rapidity, alternate between chest voice and falsetto without interruption and without taking a breath when passing from one register to the other (see Figure 14). This must be done on intervals ranging from a unison to a minor third. He continues:

> One must not be afraid to emphasise the type of hiccup which serves as passage from one register to another: **continuous exercise will soften it first, and then make it disappear**.
>
> **One must take care to not diminish the brilliance and the power of the chest voice tones, just as one must impart to the falsetto all the energy of which it is capable**. It is tempting to think that it would be better to reduce the power of the stronger register to match the weaker one; this is a mistake: experience has shown that this procedure would lead to an impoverishment of the voice [emphasis added].[f]

Significantly, García (1847a/1985, 28) motivates his limitation of these exercises to the specified range on the basis that the falsetto register is too weak below D4, while chest voice emission above F♯4 is too fatiguing.

The ambiguity inherent in García's description of register-unification exercises becomes even more perplexing when it is considered in the context of his view, referred to above, that chest voice and falsetto are produced through two different and mutually exclusive laryngeal configurations. This leads to the possible conclusion that García's register-unification exercises imply not so much a union, but rather an equalisation, of registers, which is achieved, as appears from the preceding quotation, by developing the power of the falsetto register until both the chest and falsetto registers have attained the maximum power of which they are capable. This contrasts with the prescription of Mancini (see 3.2), Garaudé (see 3.3.2) and even Duprez (see 3.3.1), which was to equalise the registers by holding back the stronger register and reinforcing the weaker one as necessary.

Although his approach is clearly mechanistic in nature, García fails to give any explicit biomechanical explanation for the supposed effectiveness of these exercises for the unification/equalisation of the registers. However, in his final published work, *Hints on Singing*, García (1894/1982, 15) states that weakness and breathiness in the falsetto (medium) register is caused by imperfect glottal closure. This may provide the rationale for his prescription to perform his register-unification exercises with full force, notwithstanding the counter-intuitive effect of exaggerating the register break as described above, as it appears reasonable to surmise that the elevated subglottal pressure will stimulate the necessary muscular development to achieve full glottal closure in the falsetto register, thereby equalising its power with that of the chest voice.

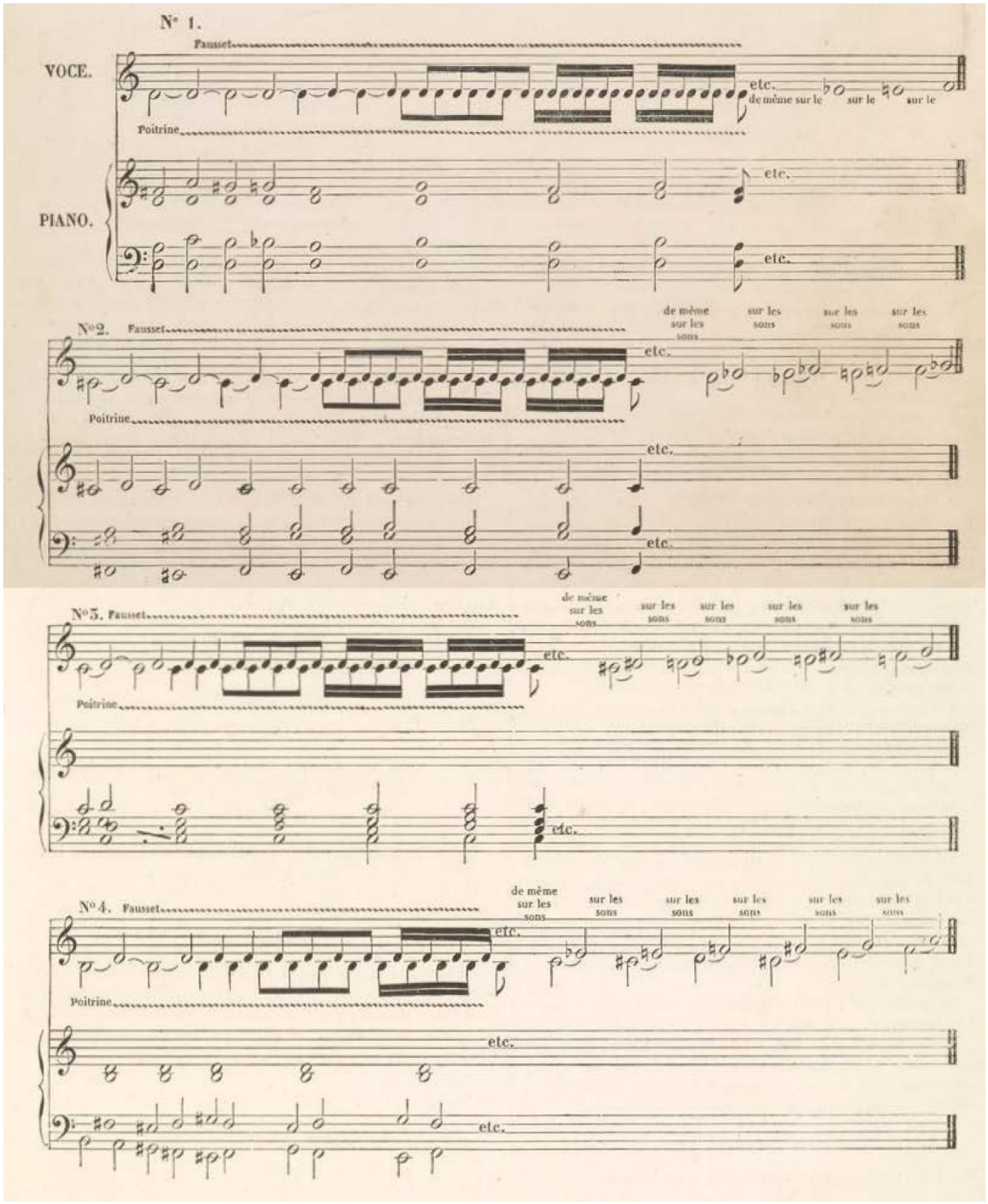

Figure 14: Register-unification exercises prescribed by García (1847b/1985, 17-18). In each case, the higher note is sung in falsetto, while the lower note is sung in chest voice.

In addition to García's assertion in the passage quoted above that the register break will disappear of its own accord through assiduous practise of his register unification exercises, we find other hints of aids to register-unification/blending scattered throughout his writing. As a primary example, he gives a

detailed description of *sons filés* (which corresponds to the Italian *messa di voce*), as a means of achieving a smooth register transition. This exercise is executed as follows:

> The pupil will start the tone piano and in falsetto with a dark timbre. As we have seen, this process fixes the larynx and tightens the pharynx. Then, without changing the position and, consequently, the tone, he will pass into the chest register, fixing the larynx more and more to prevent it from making the sudden movement which produces the hiccup at the moment of transition between the two registers. Once in the chest register, the student will raise the larynx and expand the pharynx to brighten the timbre, so that it attains all its brilliance and force towards the middle of the tone's duration. To terminate the tone, the student will do the opposite, in other words, before transitioning into the falsetto register, when the volume is reduced, he will darken the chest voice while continuing to fix the larynx in a low position and tightening the pharynx, in order to support it and avoid the jerk of the register change. Then he will slowly transition from the chest register into falsetto; after which he will soften the pharynx and end the tone. I infer this rule from the physiological fact that the larynx, being fixed in a low position by the dark timbre, can produce the two registers without moving. It is the displacement [of the larynx] that produces the hiccup which separates [the registers] so disagreeably from one another.[g] (Garcia 1847a/1985, 60-61)

Another example is the portamento exercise, which García (1847a/1985, 29) says "will aid in the equalisation of the registers, the timbres and the force of the voice." He continues to describe portamento as "the carrying of one tone to another, passing through all possible intermediate tones", and states that it can be performed with all possible combinations of loudness and ascending or descending intervals, throughout the entire range of the voice.

Showing a possible recognition that the tenor voice has certain unique characteristics, García (1847b/1985, 58) devotes a lengthy footnote in Part II of his *Traité Complet* to the proper production of the tenor's upper register. He explains that the tenor should avoid any temptation to engage the ventricular folds and pharyngeal constrictors in an attempt to give extra strength to the upper register, as this would require unsustainable effort in terms of breath pressure to maintain these elevated pitches. By leaving the glottis free to vibrate independently from the extrinsic muscles, and "relaxing all other parts of the instrument", the tone naturally becomes lighter and more slender, giving tenors the "astonishing" ability to produce the notes, A4 to D5, without any apparent effort. He continues to state that the use of this mechanism expands "…the range of [the tenor's] chest register; allows them to sing *piano* and *mezza voce* in this register and thus dispense with excessive use of falsetto: lastly, it facilitates the union of the registers, etc.".[h]

In addition to this advice, which might be summarised simply as "maintain a relaxed and open throat", García (1847a/1985, 27) said that tenors should only use *timbre sombre* above F#4, avoiding any use of *timbre clair* ("bright timbre") in this range. In other words, for García the *voix sombrée*, which

Duprez brought to France, formed an essential part of the tenor's technique in the upper register. Unfortunately, García did not express any clear view on the biomechanical reason for the effectiveness of *voix sombrée*, apart from the references given above, where he equates *voix mixte* with the darkened (i.e. using *timbre sombre*) chest voice production.

Women were similarly advised by García (1847a/1985, 26) to use *timbre sombre* in the falsetto register in order to equalise it with the chest register.

This leads us to a final aspect of García's teachings, namely the related concepts of timbre and the variation of vertical larynx height. As stated above, García (1847a/1985, 9-16) held that the various timbres, including i.a. *timbre clair*, *timbre sombre* and *timbre rond*, are resonance effects produced by the vocal tract, independently from the register configurations in the larynx, which means that the various timbres can be produced in either register. *Timbre clair* and *timbre sombre* are achieved, respectively, by a raising and lowering of the larynx (Garcia 1847a/1985, 11). A lowered larynx results from a combination of taking a full breath, which lowers the larynx and dilates the pharynx (Garcia 1847a/1985, 10), as well as the use of the vowel sound [u], which automatically lowers the larynx. The open Italian vowels, [a], [e] and [ɔ], on the other hand, tend to raise the larynx and, therefore, brighten the tone (Garcia 1847a/1985, 15).

This use of vowel qualities to manipulate vertical larynx height represents the earliest statement of what would eventually become known as covering, vowel modification and *aggiustamento* (see 3.3.74).

3.3.4. Carlo Bassini (c.1812-1870)

A perusal of the vocal method published in the United States by Carlo Bassini, entitled *Bassini's Art of Singing*, clearly shows the debt he owed to García. However, Bassini (1886, 7) was aware of the confusion that arose from García's falsetto/head denomination, and tried to clarify it by stating that the term falsetto is used in a theoretical sense to identify all tones that are not sung in chest voice. He considered chest voice as the natural tones of the human voice, but identified two further registers, namely medium (being the equivalent of García's falsetto) and head. Bassini stated further that head voice only pertains to the female voice, while chest and medium pertain to both sexes.

Dealing with the tenor voice, Bassini (1886, 7) states that the male chest voice includes the notes from C3 to C5. However, he goes on to describe the medium register as one which largely overlaps with chest voice, reaching from B♭3 to C#5. Addressing the head register, he proscribes its use by tenors on the grounds that it is effeminate.

Bassini (1886, 12) gives extensive instructions on the use of García's mechanistic register-unification exercises (to be done, according to Bassini, on notes between C4 and G4) to develop the tenor's medium register. He concurs with García that "[c]are must be taken to not lessen the force or intensity of the chest voice, in order to give the medium all the strength of which it is capable", also advising to emphasise the "hiccup" and transition between the notes without taking a breath. He acknowledges that students might find this counter-intuitive, as one would naturally want to lessen the force of the stronger register in order to equalise it with the weaker (which was precisely what was advocated by all the pre-García authorities surveyed – see 3.2, 3.3.1, and 3.3.2 above), but Bassini said that this approach would weaken the voice as a whole. According to him, correct execution of the register-unification exercises would equalise the power of both registers and facilitate transition between the two.

Bassini has no advice on how to transition smoothly between the chest and medium registers, and the assumption seems to be that a successful equalisation of the power of the two registers automatically results in the union of the registers. Bassini also falls into the ambiguity of García's treatment of the nature of the tenor's upper register, by failing to explain why tenors should practice register equalisation when he acknowledges that the tenor chest voice can reach up to C5.

3.3.5. Emil Behnke (1836-1892) and Lennox Browne (1841-1902)

Emil Behnke was a prominent teacher in London in the second half of the nineteenth century, who wrote two highly influential books on singing technique. In the first, *The Mechanism of the Human Voice*, Behnke (1890, vi) credits throat surgeon, Dr. Lennox Browne, for advising him on vocal physiology, while the second book, *Voice, Speech and Song*, was co-authored by Behnke and Browne (1886).

Behnke (1890, 4-6) commences his book with the customary lament on the decline of the standard of singing, which he ascribes, in the case of the tenors of the day, to the fact that they "disregard […] the falsetto register, singing everything, however high, in chest voice". He proceeds to blame the example set by Duprez for this sorry state of affairs.

After a thorough discussion of the state of knowledge of vocal physiology available at the time, Behnke (1890, 87) identifies three main registers in all voices, namely "thick" (the equivalent of García's "chest voice"), "thin" (the equivalent of García's "falsetto/medium" register) and "small" (the equivalent of García's "head voice"). Delving deeper into the nature of these registers, Behnke (1890, 90-93) subdivides both "thick" and "thin" into a "lower" and "upper" part, stating that male voices use "lower thick" (A3 and below), "lower thin" (A3 to F4), and "upper thick" (F4 to C5), while female voices also use the remaining "upper thin", and "small" registers (Henrich 2006, 4-5).

Like all preceding authorities, Behnke (1890, 116) states the need for "smoothing […] and equalizing [the registers]" and that singers should "aim so to blend and to unite the registers as to make it difficult even for a practised ear to distinguish the one from the other." His basic prescription, however, is to avoid carrying any given register above its proper limit, as this inevitably results in visible and audible straining (Behnke 1890, 95, 100, 103, 117). To ensure that the register transitions occur at the correct points, and to facilitate register development, Behnke (Behnke 1890, 116) prescribes a "'Vowel Scale' [that] goes from low to high in this order; oo, oh, ah, ai, ee, so that consequently the highest tones will be produced most readily when singing the vowels in the order just given" (see Figure 15, which corresponds approximately to the above order).

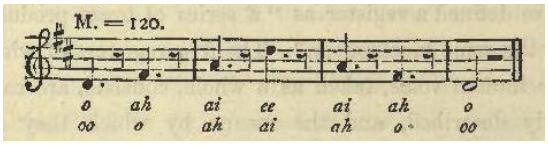

Figure 15: The "Vowel Scale" according to Behnke (1890, 116)

Behnke (1890, 117-118) continues with the following advice:

> The change from one register to another should always be made a couple of tones below the extreme limit, so that there will be at the juncture of every two registers a few 'optional' tones which it is possible to take with both mechanisms. The singer will be wise, however, to avail himself of the power of producing an optional tone with the mechanism of the lower register only on rare occasions. To force the register beyond its natural limit is, of course, infinitely worse, and should never be tolerated. The practice carries its own punishment, as it invariably ruins the voice; and tones so produced always betray the effort (frequently in a most painful degree), and are consequently never beautiful.

Although the sequence of vowels in the abovementioned "vowel scale" prescribed by Behnke appears to contradict García's advice to use [u] in the upper register as a means of lowering the larynx and darkening the tone (3.3.3 above), Behnke (1890, 118-119) nevertheless echoes García where he expounds on "mixed voice" as the means by which a tenor "bridges the break" at F4 (which he defines as the transition between "lower thin" and "upper thick"):

> The 'voce mista' is 'mixed' in this sense, that it combines the vibrating mechanism of the 'lower thin' with the position of the larynx of the 'lower thick'; that is to say, while the vibrations are confined to the thin inner edges of the vocal ligaments, the larynx itself takes a lower position in the throat than for the 'lower thin', and the result is a remarkable increase of volume without any corresponding additional effort in the production of tone.

Thus, Behnke appears to define "mixed voice" as a tone produced with a falsetto voice source mechanism and a low larynx position, which he views as typical of chest voice ("thick register"). In other words, Behnke defines mixed voice as a tone produced with the falsetto voice source (M2) mixed with the "chest voice resonance" that results from a low-larynx position.

3.3.6. Francesco Lamperti (c.1811-1892) and Giovanni Battista Lamperti (1839-1910)

Francesco Lamperti and his son, Giovanni Battista Lamperti, were revered singing teachers in Italy, and their writings are still considered to be "essential reading for singers and teachers" (Sell 2005, 26). Their main contribution to teaching practice was the formulation of the concept of *appoggio* (breath support) and the related concept of *la lotta vocale* (literally, "the vocal struggle"), which refers to the control of breath flow through a balanced opposition of the inspiratory and expiratory muscles (Sell 2005, 24, R. Miller 1986, 23-24).

Lamperti *père* (1939, 9) and Lamperti *fils* (1905, 25) subscribed to the same three-register model for female voices, namely the chest, medium (which Lamperti *père* also called mixed voice) and head registers. However, their conception of the registers in the male voice differed: Lamperti *père* (1939, 9) identified only two-registers in the male voice, namely chest and mixed voice. He indicated the starting note of the male mixed voice as A3, showing an overlap with chest voice up to D4, after which the mixed voice forms the entire upper extension of the tenor voice. Lamperti *fils* (1905, 25), on the other hand, maintained that the male voice replicates the three registers of the female voice (chest, medium and head), while also possessing mixed voice as an additional, fourth register. According to him, this fourth register is sometimes wrongly called 'falsetto'. As for the range of each register, Lamperti *fils* indicates that the male chest voice ends on F#3, where it transitions into the medium register, which reaches to D#4. Mixed voice is shown to overlap with the medium register from B3 to D#4, after which it continues to C5 to form the upper extension of the tenor voice. Lamperti *fils* makes no further mention of the male head register, which implies that he did not regard it as a usable timbre for the male operatic voice.

Lamperti *père* does not offer any advice on the unification of the registers. Lamperti *fils* (1905, 25-26) on the other hand, stipulates the following:

> On the tones [B3], [C4], [D4], and [D#4] head-resonance mingles with the chest-voice carried on from below, so that the singer sings with but half the chest-resonance. The main point is, to blend the medium register with the so-called *voix mixte*; the chief object to keep in view being to acquire an even scale from the lowest tone to the highest.

This is followed by advice to commence study with the medium register (D4 to G4 for female voices, and B3 to D#4for male voices), stating that this is the basis of a "natural and healthy high register" (G. B. Lamperti 1905, 26-27).

Lamperti *fils* (1905, 13-15) devotes a short section of his book to register-blending exercises. These exercises generally consist of broken chords spanning a fifth or octave that are performed in "portamento-style", which is reminiscent of the suggestion in Mancini's writing that portamento may be an aid to register-blending (see 3.2). He states, further, that each register transition should be accompanied by an increased jaw opening (G. B. Lamperti 1905, 10) and corresponding shifts in the location where resonance is felt. In chest voice, the resonance is appropriately felt in the chest, shifting to the hard palate for the medium register, and then to the "top of the head near the front" for the head register (G. B. Lamperti 1905, 10, 13, 24, 26). Unfortunately, Lamperti *fils* leaves tenors in the dark with regard to the location where they should feel the resonance when singing in the all-important mixed voice.

In a further discussion of register transitions, Lamperti *fils* (1905, 23) ascribes all difficulties which singers encounter with register transitions to either incorrect vocal development or faulty breathing. As an example of the former, he states: "if the chest-register be forced up unnaturally, the voice must necessarily suffer", while the principal breathing fault is "weakness of the diaphragm, which is unable to support the tone by full pressure." He continues:

> At a change of register, especially, the breathing must be calm and easy. When it is so, and when the body is in a normal position, with mouth and pharynx suitably opened, no one will experience difficulty at a change of register.

Neither Lamperti *père* nor Lamperti *fils* subscribed to the French concept of *sombrer les sons*, referred to in 3.3.1, 3.3.2 and 3.3.3 above. On the contrary, Lamperti *père* (1939, 12) believed that the tendency to "shade" the open Italian [a] by modifying it towards [o] might make a voice sound fuller and bigger in a small venue, but would deprive it of projection and brilliance in a theatre. Lamperti *fils* (1905, 79), states that this erroneous tendency to darken the open Italian [a] is only seen in "other nationalities", particularly the English. The only vowel modification he permitted was the substitution of [i] and the French [ü] on high notes with "other more euphonious" vowels, due to the difficulty that these vowels present in the upper register.

Given their opposition to the use of *voix sombrée*, it is not surprising that neither Lamperti *père* nor Lamperti *fils* subscribed to the fixed low larynx position advocated by García (see 3.3.3). Lamperti *père* (1939, 24) maintained that the larynx should remain "perfectly natural and unconstrained", which is achieved through proper abdominal breathing. Lamperti *fils* (1905, 10) merely noted that care should

be taken "that the larynx […] does not rise unnaturally high while singing; otherwise the tone will sound 'throaty', from the narrowing of the vocal tube."

3.3.7. Pedagogical writings in Germany

In Germany, Heinrich Ferdinand Mannstein (1806-1872) published a treatise, entitled *Die grosse italienische Gesangschule* in 1848. As implied by the title, the intention of Mannstein (1848, v-vi) was to provide an up-to-date exposition of Italian singing technique and teaching methods. At this point, German pedagogy was largely based on the teaching methods of the Italian castrati, as introduced to Germany by Agricola (referred to in 3.2) in his translation of Tosi's *Opinioni* (Whitener 2016, 22).

Mannstein (1848, 11) subscribed to the two-register model for male voices, being the chest voice and falsetto or head voice. Dealing with falsetto, Mannstein (1848, 12) mentions that many voice teachers of his day committed the gross error of disregarding the falsetto voice. According to him, there was a prevalent belief among his contemporaries that falsetto use, especially by male singers, would damage the vocal apparatus. Mannstein called this a "curious delusion", asserting quite reasonably that "Nature has given us nothing that would be ruinous if used sensibly." That said, he admitted that basses and baritones are rarely able to unite the chest and falsetto registers, as the "great power of these voices render the task extremely difficult." In the case of tenors, on the other hand, he viewed the union of registers as the main goal of their entire course of study.

Mannstein (1848, 89-90) was explicit in his view that register-unification consisted of an equalisation of tone quality, as opposed to the development of a unified mechanism at laryngeal level. The exercise which Mannstein (1848, 91) prescribed to achieve this register-unification echoes those given by García (see 3.3.3), insofar as they entail, firstly, the location of the register break, after which the relevant note is sung alternately in chest voice and falsetto. This, Mannstein believed, would result in the eventual blending of the disparate timbres of the two tones into a single, unified and balanced tone quality.

3.4. Twentieth and twenty-first centuries: vocal pedagogy in the age of science

It is impossible to give a comprehensive overview of the prolific pedagogical literature from the twentieth century within the limited scope of this dissertation. Therefore, the following discussion will focus on a selection of the most influential and emblematic authors.

Many, if not most, of the most influential pedagogues from this period have been steeped in scientific knowledge about the voice. Some, like William Vennard, even actively contributed to the body of knowledge on voice science through his own scientific research and collaboration with eminent voice science pioneers, such as Janwillem van den Berg and Minoru Hirano. It is surprising therefore that

confusion about the vocal registers still continues. The relevant pedagogical writings from this period are characterised by an eclectic mixture of pedagogical ideas inherited from past periods, plus some new ideas that have been absorbed from modern scientific research.

The one element of classical tenor technique on which there is general agreement amongst modern pedagogues, is the need for a form of "covering" or vowel modification as one ascends the scale (Herbert-Caesari 1936, 55, Brown 1996, Vennard 1968, 157, Appelman 1986, 89-90), as well as the need for maintaining a low larynx position (Brown 1996, 54, Vennard 1968, 61, R. Miller 1986, 152). They disagree however regarding the nature of the laryngeal mechanism that should be engaged for the correct production of the tenor's legitimate head voice. Their views can be grouped into three approaches – respectively aligning with register Strategies 2, 3 and 4 identified in sub-Chapter 1.4.7 above – as set out below.

3.4.1. Advocacy for revival of the old-school technique

a) Edgar Herbert-Caesari (d.1969)

Herbert-Caesari was a respected teacher in England, and prolific author of books on vocal pedagogy. His teachings remain influential to this day, as a cursory search of singing blogs on the internet will attest.

Herbert-Caesari (1950, p. 178; 1936, p. xix) asserted that the falsetto-based technique of the old-school *tenore di grazie* or *contraltino* tenor was aesthetically superior to the modern tenor technique, particularly because of his perception that modern tenors have poor dynamic control in their upper register, resulting in an inability to perform *messe di voce* or *diminuendi* in that part of the voice.

Having studied with Riccardo Daviesi, a *contraltino* tenor at the Sistine Chapel in Rome, he professed to base his teaching on the "purest fount of the old school", namely the *Schola cantorum* in Rome, but found it necessary to "[remould] the superstructure of old material […] under a new formula based on natural law, with the addition of modern elements and concepts" (Herbert-Caesari 1936, xx). This resulted in the formulation of many novel pedagogical ideas about vocal registration that are still widely propagated.

In broad terms, Herbert-Caesari (1936, 51-52) espoused the three-register model, comprising chest, medium and head voice, that was common in the nineteenth century. He departed from this orthodoxy, however, by introducing the novel concept of the *voce faringea* ("pharyngeal voice"), a term which Herbert-Caesari (1950, 178) appears to have coined despite his claim that it was used by exponents of the Old School. He maintained that there are "three distinct vocal membrane mechanisms producing

three individual tonal qualities: the falsetto, the pharyngeal, and the basic, or so-called chest voice". In his view, falsetto and pharyngeal voice are both produced through vibration of the thin upper ligamentous edges of the vocal folds, the difference simply being a greater degree of adduction in the latter. In chest voice, the degree of adduction is the same as with the pharyngeal voice, but the vocal folds engage in greater depth. He continues:

> "**The singer can engage at will any one of the three mechanisms separately, or any two, or all three simultaneously on certain pitches** […] All tenors, some light baritones, and all female voices have a pharyngeal mechanism, whether they know it or not, [which] lies from [F3] to [D4] normally, but can be carried to [F5] or [F#5] [emphasis added]."

The idea that it is possible to engage all three vocal membrane mechanisms simultaneously is implausible, as García already pointed out in the 1840s (see 3.3.3). In addition, this idea is completely at odds with a concept which Herbert-Caesari (1936, 39, 51) expounds elsewhere regarding what he termed "the triangle of laryngeal adjustments". According to this concept, the human voice in fact has no registers, each note being produced by a unique and ideally balanced adjustment of the vocal folds in terms of length, thickness and tension. Specifically, Herbert-Caesari (1936, 39) states that the vocal folds become incrementally "thinner, shorter, and tighter [stiffer]" as the singer ascends the scale, due to a graduated reduction in TA muscle activation, balanced by a similarly graduated increase in CT muscle activation (see Figure 16). This gradual reduction in vibrating mass is mirrored, according to this author, by a corresponding increase in vocal resonance (1936, 41-42); i.e. the smaller the vibrating mass, the greater the resonance in the vocal tract (see Figure 17).

Figure 16: Schematic representation of the "triangle of laryngeal adjustments" according to Herbert-Caesari (1936, 39), illustrating his view that the vocal folds are "thicker, longer, and looser" for low tones, becoming "thinner, shorter, and tighter" the higher the note.

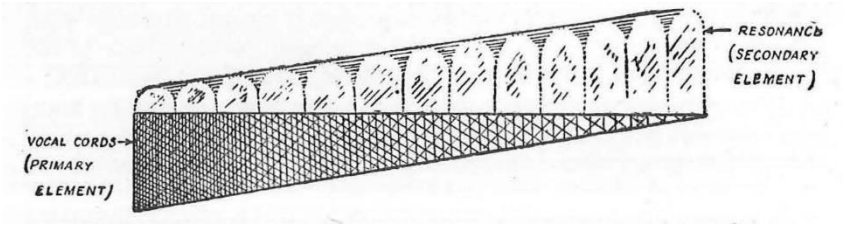

Figure 17: Schematic representation of the relationship between the "triangle of laryngeal adjustments" and vocal resonance according to Herbert-Caesari (1936, 42).

Herbert-Caesari's concept of a triangle of laryngeal adjustments aligns with the concept of CT and TA dominance (see Glossary definitions), which logically does not allow for changes in laryngeal mechanism. However, the author's assertion that the vocal folds become "shorter" for higher notes does not accord with experimental observations which have established precisely the opposite (see Glossary definitions). Thus, Herbert-Caesari epitomises the confusion that arose from the clash between old-school ideas and an incomplete understanding of the discoveries of modern voice science.

b) Alexander Mayr

Experimental research conducted by the German tenor and pedagogue Alexander Mayr (n.d., 4, 2017, 255.e20-255.e21) confirms that "pharyngeal voice" exists as a form of falsetto-based voice production. Specifically, it entails the modification of a typical countertenor falsetto by using the pharyngeal and aryepiglottic sphincters to constrict the laryngeal inlet, resulting in a timbre that is more akin to that of chest voice (see Figure 18).

Unlike Herbert-Caesari, Mayr (2017, 255.e14) does not assert that this technique is superior in all respects, being content to argue that it should be revived in the interests of historically informed performance practice. Mayr (2015a, 2015b) himself sings in this manner and is equally at home in tenor and counter-tenor repertoire, albeit in a narrow repertoire specialisation. He mentioned in a private communication to me that he is able to make a seamless switch from tenor to countertenor, without any need to habituate his vocal physiology to the relevant form of production. This is impressive indeed, but his lack of success in the standard lyric repertoire might be explained by the unorthodox tonal quality of his tenor production.

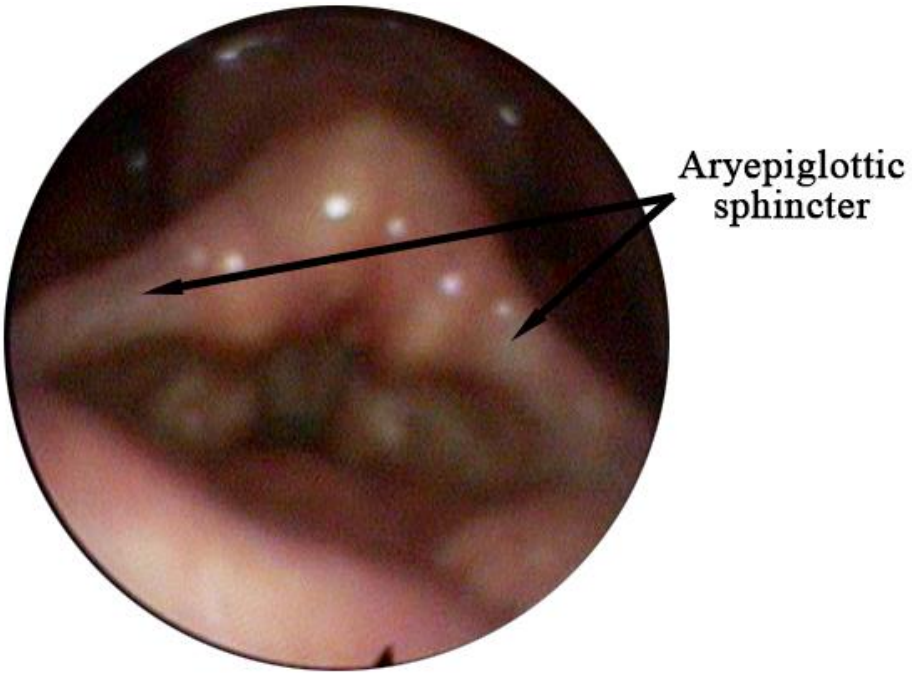

Figure 18: Laryngoscopic view of the author's vocal folds during typical pharyngealised phonation. Contraction of the aryepiglottic sphincter muscles is evinced by the thickened aryepiglottic folds, as well as the reduced cross-sectional area of the laryngeal inlet, as compared to the laryngeal configuration shown in Figure 2 on p. 6.

3.4.2. Mixed chest voice-falsetto registration: modern results with old-school methods

a) William Vennard (1909 – 1971)

In the 1960s, the highly regarded American pedagogue, William Vennard, collaborated with voice scientists Minoru Hirano and Janwillem van den Berg in clinical research that resulted in many significant contributions to the current body of knowledge. This research led him to accept the view that the extension of vocal ranges in all voice types require the use of both the chest and falsetto registers, to which end these registers need to be developed and blended. In this regard, he coined the term, "the unused register" to refer to the fact that male voices tend to neglect falsetto, while female voices tend to neglect chest voice. To remedy this, he laid emphasis on the development of the falsetto in tenor voices, and the development of the chest voice in soprano voices (Vennard 1968, 73-76). He sums up this approach in the following passage, which surprises due to a scientific vagueness that is uncharacteristic in the context of the book as whole:

> The development of the 'unused register' produces two good results. It builds muscular strength somewhere in the vocal instrument, which I shall not venture to identify, but which I am sure is valuable to the singer. The laryngeal musculature is given a special kind of exercise in one extreme register which the opposite extreme will not provide, but which would be generally beneficial. Second, this practice gives the singer a 'feel'

> of something that he should be doing but which he probably does not when he uses only the other mechanism (Vennard 1968, 76).

Vennard (ca.1960a, ca. 1960b) left us with two recordings of lessons with a mezzo-soprano and tenor, respectively, which illustrate his "unused register" approach. Listening to these lessons, the mezzo-soprano seems to benefit enormously from the development of her chest voice, while the emphasis on falsetto with the tenor has a less successful outcome.

b) Oren Brown (1909 – 2004)

Oren Brown was a respected singing teacher with extensive knowledge of the physiology and functioning of the human voice, due to his 16-year long collaboration with members of the otolaryngology department at Barnes Hospital in St. Louis in the treatment of voice disorders (Brown 1996, ix-x). He subscribed to a more scientifically founded four-register model and number-based identification (Brown 1996, 51).

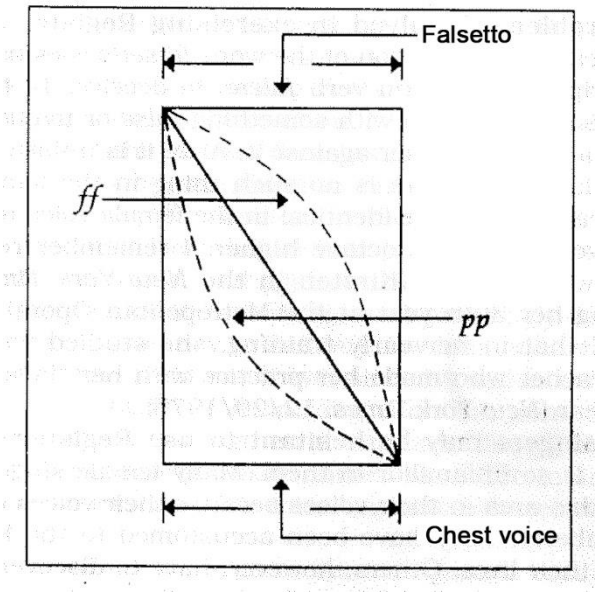

Figure 19: Schematic illustration of register-blending according to Brown (1996, 53).

Brown (1996, 52) equates an expanded range with multi-register singing in all voice types. However, the correct use of multiple registers requires a "register adjustment", which consists of learning "to bridge over one register into the range of another and add the second register without letting go of the first". The result is mixed registration (the *voix mixte* of old – see 3.3.1 and 3.3.2), which is produced when the CT and TA muscles are in dynamic balance. In this way, the student learns to take register 3 (falsetto) right to the lowest note, and register 2 (chest voice) "almost to the top", of his/her range (Brown 1996, 54). The resulting blend is reminiscent of the now-familiar schematic representation of

TA-CT dominance with two opposing triangles (see Figure 11 on page 17 and Figure 21). However, the schematic illustration given by Brown (1996, 53) as shown in Figure 19 is more sophisticated, as it shows varying proportions in the mix of the two registers that result from intensity/volume variations, while the schematic representation in Figure 11 shows a linear transfer of dominance.

To start learning how to smooth over the register break, Brown (1996, 56) prescribes as a first exercise, the singing of descending *portamenti* on the interval of an octave, the top note being sung in falsetto with a transition into chest voice for the lower note, which is repeated on descending semitones. The student will inevitably encounter a register break at the point of transition, which must be dealt with as follows:

> A 'break' occurs when the light, upper mechanism reaches the lower, heavier mechanism and suddenly lets go. At that point, feel a sense of yawning space at the back of your throat and let the tones be even lighter and more breathy. This helps to bridge over the gap with no perceptible break. […] Blending Registers 3 [M2] and 2 [M1] is the foundation of the 'seamless scale'. Tenors need to exercise the lower part of the Register 3 [M2] voice in order to manage the [D4] to [A4] range […]

According to Brown (1996, 54), it is necessary to keep the larynx in a low position throughout, as "[i]t is impossible later to develop the operatic or classical tone if the larynx is raised". He continues:

> A low larynx position can be induced by the feeling of a beginning yawn — no pulling down! The position can also be gained with the sensation of a raised soft palate, which induces the larynx to lower reflexively.

Once the above exercise is mastered, the student does the same with ascending *portamenti* on an octave, taking care that "[no] weight of quality from a lower note […] be carried into the next higher note" (Brown 1996, 57).

c) Ralph Appelman (1908-1993)

Ralph Appelman (1986, 89-90), a highly regarded contemporary of William Vennard, holds the view that, "[i]n the human voice, registration is a physiological and acoustical fact". However, he adds that, while this reality is acknowledged by most singing teachers, the average professional singer is likely to believe that the human voice has no registers, or "conceives of the vocal scale as one long extended register." This is because "[m]ost professionals are natural singers who have perfect body coordination and have never really confronted the register problem". Continuing in this vein, he pours cold water on the idea that all aspiring singers have the ability to achieve perfectly united registers:

> The single-register voice is not altogether a matter of vocal education. Some voices, through practice, may become homogeneous and uniform in quality and emission, but

> such an achievement is hardly within reach of all voices. A beautiful voice that fulfills the ideals of Western vocal culture is a gift of birth, and methodical teaching is not the principal element in its production (Appelman 1986, 87).

In general terms, Appelman (1986, 88) echoes García's view (see 3.3.3) that the upper register of the tenor voice is produced by blending the chest voice with falsetto through use of the "closed or dark timbre". He identifies three register transitions in the tenor voice, being situated at A3, F4 and B4, respectively. For added clarity, he provides a registration chart (Figure 20) indicating the tenor's chest voice as extending all the way to B4 (Appelman 1986, 91), which would imply that this is the location of the only true change in laryngeal mechanism, while the remaining transition points at A3 and F4 consist of resonance adjustments. However, this appears to be contradicted on the very next page, where Appelman (1986, 92) indicates that the transition into the upper voice of the tenor voice is situated at F4, which he considers to be the most troublesome transition, entailing as it does an "alteration of phonatory mechanism as well as a change in the resonating system." Perhaps he considers such inconsistencies to be moot, given his view that methodical teaching has very little to do with a singer's success in overcoming registration difficulties.

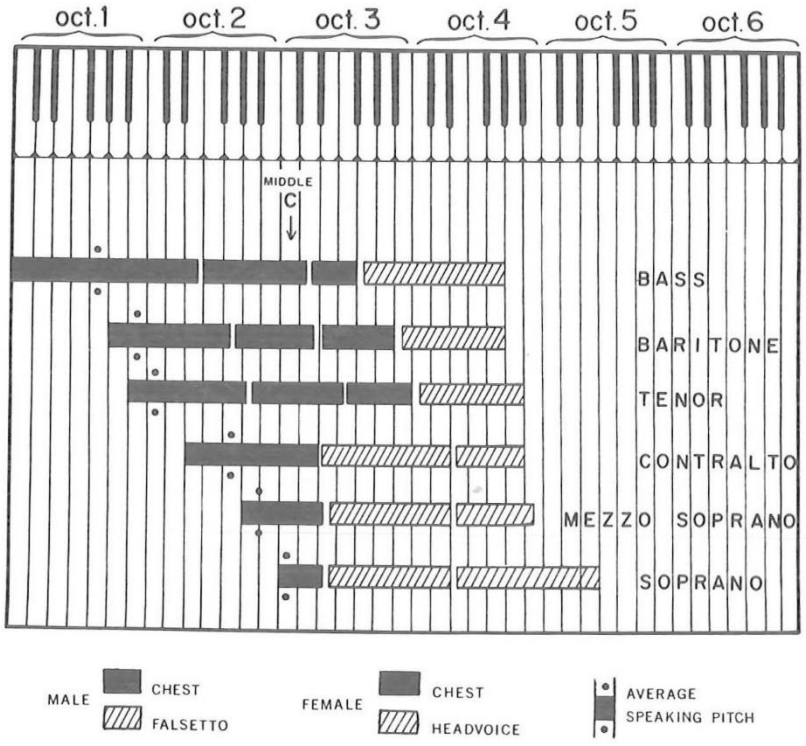

Figure 20: Registration chart with the pitch ranges of the registers by voice type according to Appelman (1986, 91)

d) Anthony Frisell (d. 2019)

The American pedagogue Anthony Frisell's emblematic book *The Tenor Voice* arguably sets out the most systematic approach to mechanistic register-blending found anywhere. Frisell (1968, 18) recognises the existence of only two registers, namely chest voice and falsetto, which he prefers to simply call the "lower register" and "upper register". Although Frisell (1968, 12) talks of register-blending, the following quote makes it clear that his approach is aimed at fusing the chest voice and falsetto into a single, homogeneous mechanism:

> The requirements for mastering the art of singing are to know the function of the two vocal registers and develop them so that they function together as a single unit of quality and strength throughout the entire vocal range (Frisell 1968, 16).

Frisell (1968, 21-22) acknowledges that the old-school *tenori di grazia* sang their high notes in a way that is no longer acceptable, but disagrees with "[m]ost present day methods of teaching [that] use vocal exercises which force the lower register upward toward the break area." He maintains that the chest voice is physiologically incapable of upwards extension, being subject to an absolute limit at E4. The falsetto, on the other hand, can be extended both up- and downwards, with the result that he regards the falsetto as the true foundation of the tenor voice.

In line with this view, Frisell (1968, 35-41) prescribes a series of exercises in pure falsetto which are aimed at extending and strengthening the falsetto register throughout the singer's range, thereby creating an overlap of the falsetto with all the notes of the chest voice. Only once the falsetto is established throughout the singer's range, may he commence "swelling and diminishing" exercises in chest voice in order to "add the bite of the lower register to the smooth quality of the falsetto." This "assures the singer that [the action of the chest voice] is never used separately, but in conjunction with the falsetto." The resulting blend of registers is illustrated schematically in Figure 21. The latter schematic bears a striking resemblance to the schematic representation of CT and TA-dominance in Figure 11 on p. 17, which reinforces the notion that registration issues can essentially be resolved through the skilful balancing of CT and TA activation.

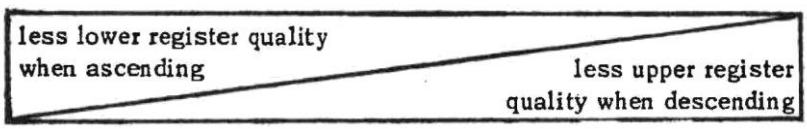

Figure 21: Schematic representation of the relative blends of chest voice (lower register) and falsetto (upper register) throughout the range of an ideal tenor voice according to Frisell (1968, 24).

e) Stephen Austin

Stephen Austin (2005, 250), a prominent American voice teacher who regularly publishes papers in peer reviewed journals, acknowledges that good results can be achieved with the "top-down" approach exemplified by the likes of Frisell and Brown. However, his approach represents an inversion of Frisell's method, inasmuch as he views the chest voice, and not falsetto, as the true foundation of the voice as a whole. Consequently, Austin (2005, 246, 250, 2004, 201) places great emphasis on the development of the chest voice for all voice types, preferring to work at "integrating [the chest voice quality] into the rest of the vocal mechanism", rather than "bringing the unique qualities of the falsetto into the singing range." However, Austin (2007, 61, 2005, 248) states clearly that the chest voice remains limited in range, with the result that his pedagogical aim is not to extend the chest voice upwards, but rather to integrate the desirable qualities of the chest voice into the singer's entire range.

He allays the common fear that chest voice development will result in singers forcing the chest voice too high, which would lead to a loss of high notes:

> On the contrary, the high voice is often the real winner in this effort, gaining in richness, range, and ease. The ability to sing a greater range of dynamics is also improved (Austin 2005, 245).

Austin (2005, 246-247) nevertheless acknowledges that some beginner students may have difficulty in gradually tapering TA muscle activity when entering the upper register. To remedy this, he prescribes García and Bassini's register-unification exercises (see Figure 14 and 3.3.4 above) – which he incongruously prefers to call "register-breaking" exercises – with certain modifications: In the version prescribed by Austin (2004, 201), the student alternates between falsetto and chest voice on descending intervals of a third or fifth, the top note always being the falsetto tone. In a further modification, Austin extends the range in which this exercise is done all the way to C5, the student's abilities permitting. He explains the rationale for this exercise as follows:

> The pedagogical principle is that the TA will engage at a level that is appropriate for the pitch and intensity and will transform the falsetto into the legitimate head voice (Austin 2004, 201).

The next step is to develop proper coordination between the CT and TA muscles in order to make the register break disappear. To this end, Austin (2005, 248) prescribes the by-now-familiar *messa di voce*, which he describes as "the 'gold standard' for hundreds of years for accomplishing this goal of even scale." In Austin's version of this perennial favourite, the student is instructed to start and end the exercise in a "light head quality voice", leaving it unclear whether he expects the student to transition from pure falsetto into chest voice as was the case in the old-school teaching (see 3.3.3), or whether he

agrees with the view of McCoy (2003, 406-407), namely that the exercise is best performed with a chest voice mechanism throughout (see 3.4.3.b)).

3.4.3. The one-register approach: it is chest voice all the way

a) Richard Miller (1926 – 2009)

Richard Miller was a leading tenor in Germany, before becoming what can justly be considered a doyen of vocal pedagogy in the latter half of the twentieth century. Although his views do not, on the face of it, align with the single-register model, Miller (1993, 3-7) is included in this chapter due to his strenuous opposition to the practice of falsetto development and register-blending or -unification, especially in his treatment of the tenor voice.

Miller (1986, 24, 1993, 25) was strongly influenced by the writings of the Lampertis, especially as regards the use of *la lotta vocale* in breath support. Drawing on the "historic Italian school" of singing, he defines three registers in the male singing voice, namely chest voice, *voce mista* (*voix mixte*) and legitimate head voice, which he often refers to simply as "head voice" (R. Miller 1986, 115-116, R. Miller 1993, 2-3). These three registers are separated by two transition points, which Miller (1986, 116-117, 1993, 2-3) refers to as the *primo passaggio* ("first register transition") and *secondo passaggio* ("second register transition"), respectively, while the area between these transition points is referred to as the *zona di passaggio* ("transition area").

The location of the passaggio points which Richard Miller (1986, 117) gives for tenor voices varies according to *fach*. For example, the *zona di passaggio* in the heaviest tenor voice, being the *tenore robusto/drammatico*, lies between C4 and F4, while the *tenorino*, at the other extreme, will encounter the transition area between F4 and B♭4.

The register transitions which he identifies are described as perceptual timbre shifts brought about by a "[d]ynamic balancing among the laryngeal muscles and the resonator tract" (R. Miller 1993, 3). As the following passage shows, this "dynamic balancing among the laryngeal muscles" aligns with the concept of CT and TA dominance:

> Increased thyroarytenoid activity is associated with 'chest' voice, while increased cricothyroid activity is associated with 'head' voice. The vocal fold tissues respond in complex ways within both actions, and the two forms of muscle function do not occur completely independent of each other. The vocal folds elongate and thin for the singing of high pitches and they shorten and thicken for low pitches. The cricothyroid muscles largely determine vocal fold length (R. Miller 1993, 7).

Miller (1993, 129, 1986, 122) acknowledges that the laryngeal conditions in falsetto and legitimate head voice are similar inasmuch as the vocal folds are stretched and thinned under CT muscle action in both cases. However, he asserts that falsetto and legitimate head voice are not synonymous, the latter being distinguished by a more complete adduction of the vocal folds, compared to the relatively incomplete adduction in falsetto.

In line with this view, Miller (1993, 130) strongly opposes any use of falsetto as a systematic tool for the development of the tenor's legitimate head voice. According to him, "[t]he tenor who has relied on falsetto in the hope of developing the upper voice almost never achieves a professionally acceptable vocal timbre." He, similarly, opposes the notion that legitimate head voice can be developed through exercises aimed at blending falsetto into chest voice. This, Miller (1986, 61) maintains, is "a futile practice that stems from a misunderstanding of the physiologic events of falsetto."

To clear up any confusion around his use of the term, *voce mista*, he states as follows:

> The male middle voice (*zona di passaggio*) is the crucial area in determining whether or not smooth register negotiation will take place from the lowest to the highest range of the singing voice. If the thyroarytenoids continue unabated in their action as pitch rises, the vocal quality known as chest voice will be carried up into the middle voice register. In contrast, introduction of the timbre known as *voce mista* brings about early balanced mechanical action between the thyroarytenoid and the cricothyroid muscles (R. Miller 1986, 118).

This "early balanced mechanical action" between the TA and CT muscles is necessary to avoid the use of the "calling voice", a polite term for "yelling" used by Miller (1986, 116-118). Use of the "calling voice" is considered a vocal fault in classical singing, and is often referred to as "register violation" (D. G. Miller 2000, 134).

b) Donald Gray Miller, Scott McCoy and Ramón Regidor Arribas

The single-register view is understandably difficult to defend against the weight of tradition, which possibly explains the dearth of authors who unambiguously espouse the view that the tenor's upper register is simply an upwards extension of chest voice. Donald Gray Miller (2000, 43-44, 58), Scott McCoy (2012, 144, 148) and Ramón Regidor Arribas (2016, 1-5) lend a tentative voice to this minority view. For these authors, all "registration events" in the tenor voice can be ascribed to resonance phenomena, which typically occur when the vowel formants "cross over" and interfere with the fundamental frequency of the tone being produced. This places resonance adjustments through vowel modification ("covering") at the core of tenor technique. In fact, covering is precisely what enables tenors to carry their chest voice up well beyond its apparent natural limit (D. G. Miller 2000, 144-145, McCoy 2012, 151-153).

This view is echoed by the Spanish tenor and pedagogue, Ramón Regidor Arribas (2016, 3), who sees a clear break with the *bel canto* past in the technique of the post-Duprez tenor:

> Having arrived at this point, it is necessary to explain the basic elements of this new vocal technique, known as the *romantic technique*, which changed the way people thought about singing and resulted in the *bel canto* singer being banished forever. We can summarise them in two points: 1st) The use of a very deep, full and forceful costal-diaphragmatic-abdominal breath, which made it possible to exert strong pressure on the vocal cords to produce and sustain a bright and powerful sound. This was at odds with the *leggerezza di fiato* [lightness of breath] which was characteristic of *belcantismo*, which used a high, costal-diaphragmatic type of breath. 2nd) The covering of high notes through the *passaggio* mechanism, in other words, the shading or darkening of the voice, especially when going from the middle to the high range, which some have called *voce negra* [literally: black voice], which enabled singers to produce all their high notes in full voice, without using the falsetto, being the resource which *bel canto* singers used to produce a bright tone. But, furthermore, it was possible to extend the tessitura of voices upwards, so that contraltos were transformed into mezzo-sopranos, mezzo-sopranos into sopranos, basses into baritones, and baritones into tenors. [i]

The brevity with which the aforementioned authors address the subject, together with an absence of supporting scientific references,[16] detracts from the persuasiveness of their view that the tenor's legitimate head voice is produced with a chest voice laryngeal mechanism (M1). This is unfortunate, as the single-register view may gain more traction if it is supported by scientific findings.

[16] Donald Gray Miller (2000, 144) expressly states that the scientific data in this regard is inconclusive.

4. DISCUSSION

It is clear from the analysis in Chapter 3 that there is no single, consistent and unified body of knowledge on singing to be found either in the historical writings of authorities on the Old Italian School of Singing (up to and including García), or the contemporary writings of self-professed adherents to the old-school tradition, as is often claimed. Authors from the post-García era generally acknowledge that the modern tenor produces a vastly different sound from that of the old-school *tenore di grazia*. Yet, many continue to adhere to the old-school register-blending or -unification methods as a means of achieving the modern legitimate head voice.

The persistence of the old-school practices can partly be explained by the nature of the teaching process, which involves the direct transmission of a rich and vibrant artistic tradition from teacher to student in the context of a highly personal relationship of trust. However, ideas also tend to survive when they are sufficiently flexible to adapt to changing times. This certainly holds true in the case of register-blending or -unification, which evolved significantly in the nineteenth century in response to the changed vocality of the tenor voice in the post-Duprez era. In particular, the analysis in Chapter 3 reveals the following:

- The purported use of "mixed voice" (as opposed to reinforced falsetto or *falsettone*) became the established orthodoxy with regard to the tenor upper register.
- The writings of Garaudé, García and Bassini gave birth to, what I term, mechanistic voice training through exercises with an apparently plausible scientific basis that are explicitly aimed at the development of the falsetto mechanism and its fusion with the chest voice mechanism.
- It became the norm in operatic technique to sing with a darkened timbre by maintaining a permanently low larynx position.

Apart from the minority of adherents to the single-register approach covered in sub-Chapter 3.4.3, these three elements remain the main pillars of contemporary approaches to the development of the operatic tenor's legitimate head voice. However, as the following discussion will demonstrate, the three pillars in question may not all stand on equally solid foundations.

4.1. Mixed voice

The persistence of mixed voice as a pedagogical concept has elicited significant scientific interest. Although many researchers accept it as axiomatic that mixed voice exists as a separate or hybrid laryngeal mechanism, and despite the significant number of studies documented in the scientific literature, it has never been observed to exist as an independent or hybrid laryngeal mechanism. In fact, the scientific literature suggests the contrary.

For example, experiments by Castellengo et. al. (2004, 5-6, 2007, 3,6) aimed at identifying the laryngeal mechanism that underlies the production of the "mixed voice" perceptual quality, showed that mixed voice is always produced in either M1 or M2, the researchers finding no evidence of an intermediate mechanism. The research in question suggests that singers can intentionally simulate the sound quality of another mechanism (i.e. M2 while phonating in M1, and vice versa) by adjusting parameters such as sound intensity and the sound spectrum, especially the singer's formant (Castellengo, Chuberre and Henrich 2004, 5, Castellengo, Lamesch and Henrich Bernardoni 2007, 6). In a subsequent study, Roubeau and co-workers (2008, 436) showed that male singers generally use M1 to produce "mixed voice", while female singers tend to produce the said perceptual quality in M2.

These findings support the assertion of García that laryngeal mechanisms cannot be mixed (see sub-Chapter 3.3.3), and lead to the conclusion that mixed voice exists purely as a perceptual category which is produced either in M1 or M2. Švec et. al. (2009, 22-23) suggest that, in the case of male voices, this perceptual quality is produced by singers who are able to independently abduct the posterior glottis during normal chest voice phonation (see Figure 22).

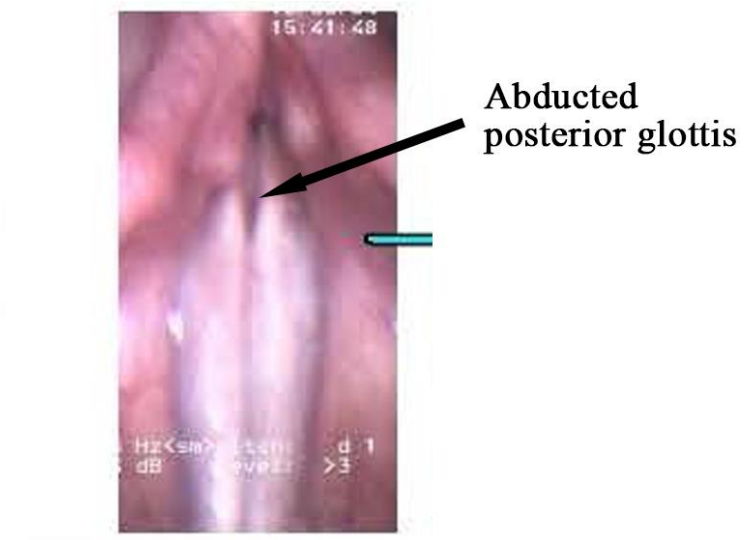

Figure 22: Abduction of the posterior (cartilaginous) glottis during normal chest voice (M1) phonation postulated to be a means of producing the perceptual quality of "mixed voice". Source: Švec et. al. (2009, 22)

4.2. Register-blending or -unification

If one accepts that mixed voice does not exist as an independent laryngeal mechanism, it calls into question whether the old-school register-blending or -unification practices have any place in modern vocal training, in particular the training of the tenor's legitimate head voice.[17]

A common-sense observation that militates against such mechanistic voice training is that, if it were possible to develop the falsetto voice source mechanism until it is equal in power to, or merges with, the chest voice mechanism, one would expect the upper register of countertenors (who sing almost exclusively with a falsetto voice source throughout their range) to rival that of tenors. However, the perceptual quality of a developed countertenor voice suggests that falsetto development simply leads to a stronger falsetto. For this reason, one could also question the notion that the tenor's legitimate head voice consists of a fully adducted falsetto mechanism, as is often found in the pedagogical literature (see sub-Chapter 3.4.3.a), for example).

4.2.1. The source mechanism of the tenor's legitimate head voice

The answer to the true nature of the tenor's legitimate head voice may be found in an underappreciated scientific observation referred to by Titze (1994, 256, 261), namely that the chest voice mechanism entails two separate adductory gestures of the vocal folds, corresponding to the upper ligamentous edges and the lower muscular edges of the vocal folds, respectively. These two adductory gestures can respectively be referred to as LCA adduction, given that the vocal ligament (which forms the upper edge of the vocal fold) is adducted by the action of the LCA muscle, and TA adduction, given that the lower edge is adducted by the action of the vocalis muscle (Titze 2014, 2093).

To understand the significance of the dual adductory gestures described by Titze, it is necessary to look more closely at Van den Berg's myoelastic-aerodynamic theory of phonation, specifically the aerodynamic aspect of that theory which invokes the so-called "Bernoulli Effect".

Van den Berg explained the self-sustaining nature of vocal fold vibrations with reference to one of the laws of fluid dynamics, namely the Conservation of Energy Law (Titze 1980, 496), as formulated by the Swiss mathematician and physicist, Daniel Bernoulli (1700-1782). This law states that the net energy at any given point in a system of air or liquid flow will always be constant. Given that the total

[17] The intention is not to challenge the use of register-blending or -unification terminology to provide perceptual guidance during vocal training (McCoy 2012, 144), but relates to mechanistic approaches where a student is directed to devote substantial time and energy to the isolated development of the falsetto mechanism in the hopes that it will somehow merge with the chest voice to form a single, continuous mechanism.

energy in a system is equal to the product of its potential energy (in our case, air pressure) and kinetic energy (air velocity), it follows that any increase in the velocity of flow must be accompanied by a corresponding decrease in pressure, and vice versa. This leads to the counterintuitive, but scientifically proven fact that, where there is a constriction in a tube (as is the case with the constriction that is created when the vocal folds are drawn together), the pressure at that point will drop in proportion to the increase in airflow velocity (Titze 1994, 70-71). This well-known suction effect at a point of constriction has become known as the "Bernoulli Effect" (Vennard 1968, 38).

In terms of Van den Berg's theory, it is this drop in air pressure – resulting from the constriction of partially adducted vocal folds – which completes the process of adduction by sucking the vocal folds together (Titze 1994, 80).

Titze (1994, 81-82, 91-96, 1988, 1537) points out that the Bernoulli Effect by itself is not sufficient to explain the phenomenon of self-sustaining vocal fold oscillation, as the Bernoulli forces exerted on the vocal folds would be equal in both the medial (closing) and lateral (opening) phases of motion, thereby cancelling each other out (Titze 1980, 496).

The fact that vocal fold vibrations are self-sustaining implies the presence of a periodic asymmetric force which continuously transfers energy to the vibrating vocal folds. Using a child on a swing as an example, Titze (1994, 84-86) explains that the source of this asymmetric force can originate within the oscillating system itself, as when the child appropriately synchronises postural and momentum changes (by leaning back and kicking out her legs) with the swinging motion, or outside of the system, as when a parent periodically gives the child a well-timed push. In the model proposed by Titze (1980, 91-96, 1988, 1546), the first-mentioned scenario (i.e. the periodic asymmetric force originates within the system) applies to phonation with a chest voice source mechanism (M1), while the latter scenario applies to phonation in falsetto (M2).

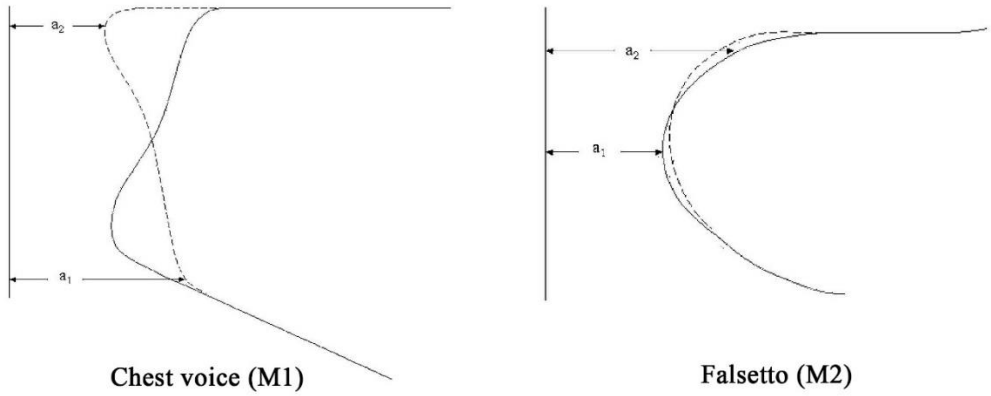

Figure 23: Schematic representation in coronal section of vocal fold displacement from the midplane of the glottis in chest voice (M1) and falsetto (M2). Source: Titze (2008, 2740).

Let us consider the case of chest voice first. It is a well-documented phenomenon that the mucosal wave in the vocal fold cover propagates in the direction of airflow (Titze 1988, 1540), i.e. from the bottom to the top of the vocal fold, resulting in a vertical phase-difference in the waving motion (Vahabzadeh-Hagh, Zhang and Chhetri 2018, 1417, Vennard 1968, 66, Titze, Jiang and Hsiao 1993, 58, Thurman, et al. 2004, 10). This happens in the following manner: Once the vocal folds are adducted in preparation for phonation, subglottal pressure will build up below the vocal folds, eventually pushing the bottom edges of the vocal folds apart. This creates a convergent glottal shape. As the subglottal pressure continues to rise, the top edges will also start to move apart. At this point, elastic recoil will cause the bottom edges to start their return journey to the midline, resulting in a divergent glottal shape (Hirano and Bless 1993, 29-30, Titze 1994, 94-96, Zhang 2016, 2618-2619).

Experimental observations confirm that a convergent glottal shape will have a higher mean intraglottal pressure than a divergent glottal shape (Story and Titze 1995, 1258-1259, Titze 1988, 1538-1539). Consequently, this continuous alternation of convergent and divergent glottal shapes causes the asymmetry of the aerodynamic driving forces in the glottal airstream. This then pushes the vocal folds apart while the glottis is convergent, and pulls them together again while the glottis is divergent (Titze 1994, 96-100, Titze 1980, 504-505, Zhang 2016, 2620).

Turning now to falsetto, we find a vibratory mode where the vocal folds are stretched so thinly that the mucosal wave is negligible or even completely absent (Vennard 1968, 67). As a result, the medial contours of the vocal folds remain identical during the opening and closing phases of the glottal cycle. In this scenario, Bernoulli's Law predicts that the aerodynamic pressures will be symmetrical throughout the glottal cycle, thereby cancelling each other out. Since the required asymmetric driving force cannot be generated within the vibrating system through non-uniform tissue movement, an external mechanism is needed (Zhang 2016, 2620).

This mechanism is provided by the inertia of the air particles moving in the vocal tract, which works as follows: when sufficient subglottal pressure has built up to push the vocal folds apart, some pressurised air will escape through the glottis. The escaping air particles will collide with the particles in the vocal tract above the glottis, causing the column of air in the vocal tract to start accelerating away from the glottis. Since air has mass and, therefore, inertia, the air column will tend to maintain its momentum away from the glottis, even after the vocal folds have started returning to the midline under the influence of their inherent elastic properties. As the glottal airstream is shut off by the closing vocal folds, the inertive movement of the air column away from the glottis effectively creates a wake of reduced air pressure, which serves to assist with the drawing-together of the vocal folds. In each case, the net force vector is in phase with the vocal fold motion (Titze 1988, 1537-1538, Zhang 2016, 2620).

It follows that, where the propagation of a mucosal wave is constrained by inadequate surface tissue mobility, as is the case with falsetto phonation, self-sustaining vibrations are impossible without the inertive load provided by the air column in the vocal tract (Story and Titze 1995, 1248, Titze 1988, 1539). The chest voice source mechanism, on the other hand, creates its own oscillation conditions through the mechanics of the mucosal wave (Titze 1988, 1569, 1551).

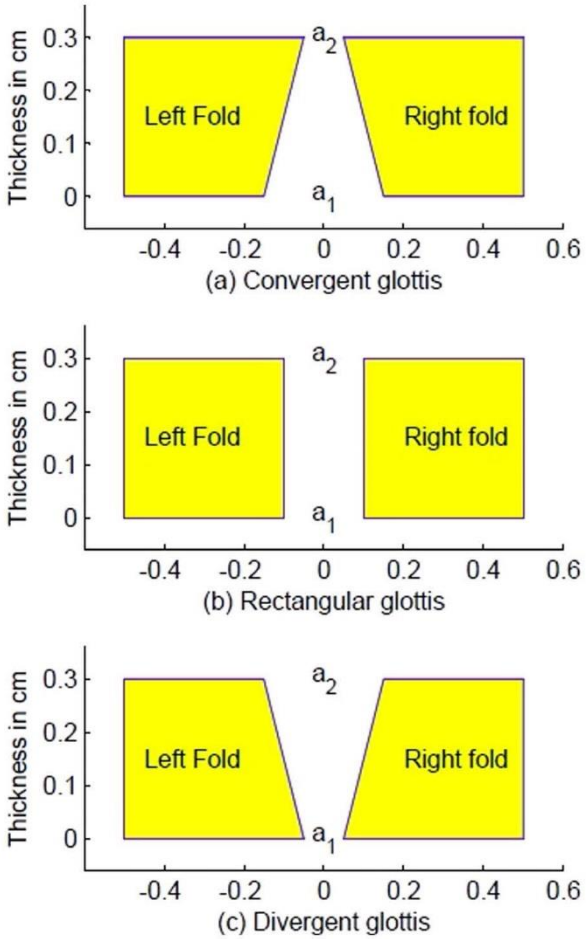

Figure 24: Schematic representation of three possible glottal shapes: (a) The convergent shape results when the upper edges of the vocal folds are more adducted than the bottom edges (typical of M2); (b) The rectangular shape is the result of equal adduction of the upper and bottom edges (typical of M1); and (c) The divergent shape results when the bottom edge is more adducted than the upper edge (phonation difficult with this configuration). Source: Titze (2014, 2093).

Titze's contribution to the myoelastic-aerodynamic theory places glottal geometry (and by extension, the dual adductory gestures described above) at the centre of vocal registration. Falsetto is characterised by a permanently convergent glottis, while the glottal shape alternates between convergent and divergent while phonating in chest voice (see Figure 23). In the case of the chest voice configuration,

Titze (2014, 2092) has determined that a rectangular, or near-rectangular, glottal shape[18] represents the most efficient, and therefore ideal configuration for self-sustaining vocal fold vibration.[19] As appears from Figure 24(b), the rectangular glottis presents as parallel contours along the medial surfaces of the vocal folds.

At low frequencies, the rectangular shape can be maintained purely through the deformation of the vocal folds during contact, which causes the vocal fold edges to square up to each other (Baken and Orlikoff 2000, 423). However, as the frequency rises with a concomitant increase in the stiffness of the vocal ligament, it becomes necessary for the vocalis muscle, which adducts the lower edge of the vocal fold, to actively track and match the passive stiffness in the vocal ligament, which forms the top edge of the vocal fold (Titze 2014, 2093). This is an inherently complex and challenging manoeuvre due to the vastly different biomechanical properties of the various parts of the vocal folds. Incremental, linear elongations of the passive tissue (specifically, the ligament and epithelium) produce a logarithmic stress-strain response, while the stress-strain response of the active tissue (the TA muscle) is more linear (Titze 1980, 506-507, Zhang 2016, 2616).

The preceding observations have two major implications. Firstly, to maintain the rectangular glottal configuration, the contractile force of the vocalis muscle must increase along an exponential curve as pitch rises in order to match the non-linear stress-strain response of the passive tissue. Secondly, the ability to maintain a dynamic balance between the adductory forces in the active and passive tissues of the vocal folds at high pitches implies exceptional fine motor skills.

4.2.2. Solving the mystery: is the tenor's legitimate head voice a question of brawn and brains?

Titze (2018, 49) has suggested that the elusive "mixed voice" mechanism of the tenor's upper register is defined precisely by the ability to balance the adductory forces in the active and passive tissues of the vocal folds to maintain the rectangular glottal shape. However, chest voice (M1) and falsetto (M2) are distinguished by vibrational mode, and not simply the underlying muscular activity.[20] I would argue,

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[18] Given that the aerodynamic forces in the glottal airstream continuously deform the vocal fold cover to create the alternating convergent and divergent glottal shapes during chest voice phonation, the reference to a "rectangular glottal shape" relates to the pre-phonatory glottal shape, or the shape which the glottis would have but for the aerodynamic deformation of the vocal fold cover.

[19] Mathematical modelling by Titze (2014, 2093) suggests that extremely high subglottal pressures would be required for phonation with a permanently divergent glottal shape. As a result, this does not represent a viable phonation strategy.

[20] See *Chest voice source mechanism (M1)* and *Falsetto voice source mechanism (M2)* in the Glossary.

therefore, that "mixed voice" defined in this manner does not offer a meaningful distinction, as the ability to maintain a rectangular glottis is not in itself a defining characteristic of the chest voice mechanism – it is a prerequisite for the presence of the mucosal wave in the vocal fold cover, which is what defines the chest voice mechanism. I would go even further and argue that identification of voice register with the underlying muscular activity lies at the root of fallacies such as the TA-CT dominance theory of registration, which was disproved empirically i.a. by Hull (2013, 39), who found no correlation between register conditions and the relative dominance of activity in the TA-CT antagonist pair.

It would follow from the above that the tenor's legitimate head voice consists in the upward extension of the chest voice mechanism (M1) through sheer strength in the TA muscle[21] coupled with great skill and control in its use. If this hypothesis is correct, pedagogical approaches that emphasise falsetto development and register-blending or -unification at a mechanistic (as opposed to perceptual) level would be of questionable utility.

4.3. Low larynx and darkened timbre

The third pillar of modern vocal technique, namely singing with a lowered larynx, arguably rests on the most solid scientific foundation, especially with regard to the tenor's legitimate head voice, due to its demonstrable biomechanical, resonance and acoustic effects.

4.3.1. Creating some slack in the biomechanical system

If one accepts that the tenor's legitimate head voice consists in an upward extension of the chest voice mechanism and that chest voice is defined by the presence of a mucosal wave in the vocal fold, any laryngeal manoeuvre that contributes to the slackening of the vocal fold cover would facilitate chest voice phonation through greater ease in the propagation of the mucosal wave. It turns out that the lowered larynx is precisely such a manoeuvre, as I shall endeavour to explain.

The conus elasticus is anchored to the cricoid cartilage, which is subject to a downward pull by the oesophagus, as well as the weight of the trachea and lungs (Vennard 1968, 60-61, Andrade 2012, 655.e22). A raised larynx will increase this downward pull, which results in a vertical stretching of the conus elasticus and a concomitant reduction in the pliability of the vocal fold cover. Lowering the larynx creates vertical slack in the conus elasticus and vocal fold cover, which has two results: The vocalis

[21] As with all skeletal muscle, stimulus and conditioning through an appropriate exercise regimen (vocal exercises in the case of singers) will lead to hypertrophy and increased strength in the TA muscle (Thurman, et al. 2004, 14)

muscle does not have to strain against a stiff membrane, and the increased pliability of the vocal fold cover facilitates propagation of the mucosal wave (Titze 1994, 195, 2012, 655.e22).[22]

4.3.2. Boosting the singer's formant

One of the acoustic signatures of chest voice is the concentration of acoustic energy in the upper harmonics, which gives chest voice a distinctly rich, fuller and ringing perceptual quality.[23] Classically trained male singers learn to enhance this inherent quality of the chest voice through cultivation of the so-called singer's formant, which consists of a cluster of the third to fifth formants around 3 kHz (see Glossary definitions). Sundberg (2013, 1-2, 1972b, 47) demonstrated that the singer's formant is produced when the cross-sectional area of the laryngeal tube is much smaller than that of the surrounding pharyngeal space, which allows the laryngeal tube to function as an independent resonator, separate from the rest of the vocal tract. In these conditions, the natural resonance within the laryngeal tube generates the third formant, a phenomenon that is usually only present in well-produced male voices.

In the experimental observations reported by Sundberg (1972b, 51), the singer's formant was strongly associated with lowered larynx singing, which causes the pharyngeal resonance space to be enlarged through a lengthening of the vocal tract and enlargement of the piriform sinuses.[24] Quantitative measurements by Sundberg (2013, 1-2, 1972b, 50) determined that a ratio of 1:6 between the respective cross-sectional areas of the laryngeal tube and the pharynx represents the ideal configuration for production of the singer's formant. This suggests that the singer's formant could be produced without a lowering of the larynx, provided that the cross-sectional area of the inlet to the laryngeal tube remains smaller than one sixth of that of the surrounding pharyngeal space.

The 1:6 ratio established by Sundberg could explain research findings which show that the singer's formant is also present in certain non-classical styles of singing, such as Chinese opera, that do not utilise a lowered larynx position (Sundberg 1988, 15). It may also explain the work of Mayr (2017,

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[22] Titze (1994, 106) speculates that some singers may be genetically blessed with a naturally thick and mobile vocal fold cover, which would enable them to maintain chest voice over a larger range without the need for vowel modification or covering (Story and Titze 1995, 1551). Such singers may be able to extend their chest voice mechanisms upwards without the need to darken their timbre with a lowered larynx.

[23] See *Chest voice (as perceptual quality)* and *Singer's formant in* Glossary.

[24] These are two vertical pockets between the aryepiglottic folds and thyroid cartilage, which serve to channel food towards the *oesophagus* during swallowing. The piriform sinuses assist in the production of the singer's formant by enlarging the pharyngeal resonance space when a low-larynx singing position is used (Sundberg 1972, 46-47, Bunch 1997, 65, 85, Appelman 1986, 49).

255.e16-255.e17, 255.e21), who found that it is possible to modify the acoustic output of the falsetto voice source (M2) to lend it a chest voice-like quality (see Chapter 3.4.1.b)). This perceptual quality, referred to as *la voce faringea* ("pharyngeal voice"), is produced through a constriction of the aryepiglottic sphincter and a simultaneous raising of the larynx, which purportedly reduces the respective cross-sectional areas of both resonators in such a way that the relevant 1:6 ratio is maintained. Thus, the singer's formant cluster can be boosted to augment the overtone energy of a falsetto voice source, thereby providing a means to mimic chest voice while using a falsetto voice source.

There are no studies documented in the scientific literature where the acoustic signature and perceptual quality of a singer's formant produced in chest voice (M1) with a low larynx position is explicitly compared with that which is produced in falsetto (M2) coupled with a high larynx position and aryepiglottic constriction, but I would predict on the basis of first principles that the latter is a sub-optimal solution due to the inherently weaker overtone structure of the falsetto voice source.[25]

4.3.3. Avoiding acoustic interference

Non-linear source-filter theory suggests that some involuntary register jumps can be explained by interactions between the voice source and the acoustic resonances in the vocal tract and subglottal tube (Zhang, Neubauer and Berry 2006, 1566). It is theorised, in this regard, that vocal fold vibrations can be disrupted by resonance interference when a resonance frequency crosses over F_0, the latter being equivalent to the vibrational frequency of the vocal folds (McCoy 2012, 149). For example, the natural resonance frequency of the subglottal system has been calculated at approximately 330 Hz (Vennard 1968, 87-88), which corresponds to the pitch of E4. The correlation between this pitch and the location of the tenor's register break may suggest a causal link. Lowering the larynx would reduce the length of the subglottal tube and potentially raise its natural resonance frequency above the fundamental frequency of the normal tenor range. The frequency cross-over that could cause interference with the vibration of the vocal folds would thus be avoided.

4.4. Implications for the training of tenor voices

Confirmation of the hypothesis that the tenor's legitimate head voice consists of an upwards extension of the chest voice mechanism would have important implications for tenor training methods, in particular the practice of register-blending or -unification in the mechanistic sense. Recent discoveries in motor learning science suggest that students acquire motor skills best when they focus purely on the targeted outcome, as opposed to the individual muscular adjustments that produce that outcome

[25] See *Falsetto (as perceptual quality)* and *Chest voice (as perceptual quality)* in the Glossary.

(Verdolini 2002, 48-49). According to this principle, and considering that Classical singing requires fine motor skill par excellence in the control of the laryngeal muscles, the outcome of focusing on falsetto development would simply be the development of a more powerful falsetto. It would likely not contribute to the skill which the tenor really needs to learn, namely how to maintain the balanced adduction of the upper and lower edges of the vocal folds in the upper register.

It is interesting to note that Echternacht et. al. (2017, 381.e8-381.e9) found that epilaryngeal constriction, which is typical of *la voce faringea* as discussed above, is a relatively common strategy used by tenors in their upper register. This is surprising, given the assertion by Mayr (3.4.1.b) above) that *la voce faringea* is a forgotten art that should be revived in the interests of historically informed performance practice. I would suggest that the use of *la voce faringea* represents a potential unintended outcome of training methods that use falsetto development and/or register blending as a means of developing the legitimate head voice. A tenor who develops a strong falsetto which fails to convert into or fuse with his chest voice as expected, might discover that he can produce a passable simulation of chest voice by adding a squeezing sensation in the throat, as described by Mayr (n.d., 4), which is in fact the subjective perception of epilaryngeal constriction. While *la voce faringea* may produce passable results, the falsetto voice source is inherently weaker in harmonic raw material than the chest voice source (see Glossary definitions of the *Chest voice* and *Falsetto* perceptual qualities).

Given that the vocal tract can only amplify frequencies that are present in the voice source (McCoy 2012, 23, 38, Sundberg 2006, 103), the use of a falsetto voice source mechanism in the upper register may not represent the optimal realisation of the singer's true potential. I would therefore argue that this is an undesirable outcome that should be guarded against when using a mechanistic register-blending or -unification approach.

Mechanistic register training methods could be defended on the grounds that they develop valuable strength in relevant parts of the laryngeal musculature as Vennard suggests (3.4.2.a) above). However, these methods ignore the essential element of skill that is required for the development of the legitimate head voice. For this reason, pedagogical approaches that emphasise the simultaneous development of skill and muscle strength (with attendant resonance adjustments) in the upward extension of the chest voice mechanism may be more likely to achieve the desired outcome.

5. CONCLUSION

The aim of the present research was to gain a greater understanding of the legitimate head voice of the modern operatic tenor, as well as the correct development thereof for realisation of the singer's full potential.

Following the introduction in Chapter 1, the historical overview of the tenor voice in Chapter 2 elucidates how the vocality of the tenor voice has changed over time and, in particular, how the modern tenor sound differs from that of the castrato-trained *tenori di grazia* of old.

The analysis in Chapter 3 shows that the practice of register-blending or -unification was central to the training of singers in general, and the tenor upper register in particular, throughout the seventeenth to nineteenth centuries. In the seventeenth and eighteenth centuries, this practice was aimed at achieving a smooth transition between chest voice and the reinforced falsetto (*falsettone*) that tenors used in their upper registers. In the nineteenth century, with the declining influence of the castrati, the practice of register-blending or -unification evolved to place the emphasis on the development of "mixed voice" for the tenor's upper register, together with the use of exercises that were explicitly aimed at the strengthening of the falsetto register and its fusion with the chest voice mechanism.

The practice of register-blending or -unification and reliance on mixed voice remains firmly entrenched in pedagogical writings from the twentieth century to the present. More recently, a minority of pedagogues have begun to call this practice into question. According to their view, the tenor's legitimate head voice consists of an upwards extension of his chest voice mechanism. Although there is no conclusive evidence in this regard, the discussion in Chapter 4 suggests that this may well be the case. It is reasonable to postulate that muscular strength – particularly in the TA muscle – plays an important role in the ability to phonate in chest voice (M1) at high pitches. Perhaps more significantly, fine motor skill – specifically the ability to maintain balanced adduction of the active and passive tissues of the vocal folds – is likely an essential component of the tenor's legitimate head voice.

The absence of evidence for a mixed or hybrid voice source mechanism in the current body of scientific knowledge suggests that mechanistic register-blending or -unification training methods are premised on an outcome that is physiologically impossible. As such, these training methods have doubtful value *per se* in the development of the tenor's legitimate head voice. While mechanistic register training methods may serve to develop valuable strength in certain parts of the laryngeal musculature, it does not assist in the development of the fine motor skills that are pertinent to the tenor's legitimate head voice. In addition, mechanistic register training methods present a potential pitfall: although the tenor's falsetto is likely to become more powerful and pleasing through diligent practice of these methods, it is unlikely to spontaneously transform into, or merge with his chest voice. This may cause the singer to

resort to pharyngeal and aryepiglottic constriction as a means of simulating the legitimate head voice while using a falsetto (M2) voice source mechanism. This is a sub-optimal solution given that the falsetto (M2) acoustic voice source is inherently weaker in harmonic raw material than that of chest voice (M1).

The research presented here suggests that pedagogical approaches which emphasise the simultaneous development of skill and muscle strength in the upward extension of the chest voice mechanism (M1) may be more effective for the development of the tenor's legitimate head voice than the mechanistic register-blending or -unification approaches that were developed in the nineteenth century. This hypothesis can be tested with a future laryngoscopic and electroglottographic investigation to confirm the nature of the voice source mechanism which underlies the tenor's legitimate head voice, as well as a controlled intervention study drawing on the field of motor learning science to assess the effectiveness of the various pedagogical approaches identified in Chapter 4.

ORIGINAL TEXT OF MAJOR TRANSLATED PASSAGES

Note: All translations are my own.

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[a] "*Il n'est pas d'élève qui ne s'aperçoive d'un changement de timbre dans sa voix lorsqu'il arrive à certaines notes. La transition doit s'en opérer avec les plus grandes précautions; de là dépend l'égalité de la voix. Le soprano, par exemple, arrive en voix de poitrine jusqu'à La, Si, Ut, du médium; puis le Si, l'Ut et le Ré sons ordinairement d'un timbre bien plus faible et qui fait disparate. Il faut pour parer autant que possible à cet inconvénient adoucir graduellement les deux notes qui précèdent celles du changement, arrondir et forcer mêmes les deux notes qui suivent. Mais j'engage bien les élèves à pousser aussi loin que possible les limites de leur voix de poitrine, car la paresse ou la crainte de faire des efforts leur fait souvent perdre cette puissante ressource.*"

[b] "*…il faut étendre autant que possible les limites de la voix de poitrine et de la voix intermédiaire ou mixte, afin d'obtenir plus de force et d'éclat et éviter les disparates dans le changement des registres.*"

[c] " … « *Suivez-moi » guerrier, terminé par une note à laquelle je n'avais jamais essayé d'atteindre, moi, tenorino d'hier, à peine mis au courant des habitudes dramatiques par un seul opéra sérieux, mes cheveux se dressèrent sur ma tête! Du premier coup je le compris: ces mâles accents, ces cris sublimes, rendus avec des moyens médiocres, n'étaient plus qu'un effet manqué, partant ridicules. Ill faillait, pour se mettre à la hauteur de cette énergique création, la concentration de toute la volonté, de toutes les forces morales et physiques de celui qui s'en ferait l'interprète….*
Eh! Parbleu, m'écriai-je en terminant, j'éclaterai peut-être; mais j'y arriverai!
Voilà comment je trouvai cet ut de poitrine qui me valut, à Paris, tant de succès, trop peut-être; car, enfin, qu'est-ce qu'un son, sinon un moyen d'exprimer une pensée? Qu'est-ce qu'une note, sans le sentiment qu'elle colore et dont elle est animée?"

[d] "*Cette voix a 2 registres: celui de poitrine et celui de tête. Pour passer facilement de l'un à l'autre, il faut adoucir le dernier son de la voix de poitrine, et renforcer le premier son de tête, comme étant plus faible par sa nature.*
Les voix de Ténor se distinguent en deux espèces. Le 1er Ténor, qui est ce qu'on appelait jadis haute-contre, atteint quelquefois le Si et le Do de poitrine, sans compter quatre sons de tête, Ré, Mi, Fa, Sol. Le Ré et le Mi graves sont presque nulles dans cette voix. Le 2e Ténor, au contraire, commence son régistre de poitrine par ces deux notes, le prolonge jusqu'à ce Sol [shown on stave] et peut y ajouter quelques sons de tête.
Dans les voix de Ténor, les sons de tête habilement employés ont un charme infini. On doit s'attacher à y donner de la [illegible], de l'égalité, de la pureté, et à les unir d'une manière imperceptible avec la voix de poitrine.
Afin de paraitre prolonger d'une note ou deux leur voix de poitrine, dans le haute, on, pour mieux unir celle-ci avec la voix de tête, les Ténors emploient souvent une qualité de son factice qu'on nomme voix mixte, en ce qu'elle participe un peu de l'un et de l'autre. Elle se prend sur le dernier son de poitrine, et peut s'étendre ordinairement plusieurs demi-tons au-delà des bornes de celle-ci. Pour bien comprendre ce que c'est cette voix mixte, il faut l'entendre par un professeur.
Un ténor intelligent peut tirer grand parti de cette ressource pour pouvoir chanter certaines phrases sans changer de registre, ou pour ôter à ce changement toute espèce de dureté."

[e] "*Par le mot registre, nous entendons une série de sons consécutifs et homogènes allant du grave à l'aigu, produite par le développement du même principe mécanique, et dont la nature diffère essentiellement d'une autre série de sons également consécutifs et homogènes, produit par un autre principe mécanique. Tous les sons appartenant au même registre sont, par conséquent, de la même nature, quelles que soient d'ailleurs les modifications de timbre ou de force qu'on leur fasse subir*"

[f] "*Il ne faut pas craindre de bien accuser l'espèce de hoquet qui sert de passage d'un registre à l'autre : l'exercice continu peut seul l'adoucir d'abord, et le faire disparaitre ensuite.*
Il faut bien se garder d'amoindrir l'éclat et la force des sons de poitrine, de même qu'il faut donner au fausset toute l'énergie dont il est susceptible. On est tenté de penser qu'il serait mieux de réduire la puissance du plus fort aux proportions de celle du plus faible ; c'est une erreur : l'expérience prouve que l'emploi d'un tel procédé aurait pour résultat d'appauvrir la voix."

[g] "*L'élève commencera le son piano en fausset et en timbre sombre. Comme on l'a vu, ce procédé fixe le larynx, et resserre le pharynx. Ensuite, sans varier la position, et, par conséquent, le timbre, on passera au registre de*

poitrine, en fixant de plus en plus le larynx, affîa de l'empêcher de faire le mouvement brusque qui produit le hoquet au moment de la séparation des deux registres. Une fois entré dans le registre de poitrine, on remontera le larynx, on remontera le larynx pour éclaircir le timbre, de sorts que, vers de milieu de la durée du son, celui-ci ait et tout son éclat et toute sa force. Pour éteindre le son, l'élève fera l'inverse, c'est-à-dire qu'avant de passer au registre de fausset, lorsque la voix est diminuée, il assombrira la voix de poitrine, toujours en fixant le larynx en bas et en resserrant le pharynx, afin de l'appuyer, et l'éviter la saccade du changement de registre. Alors il passera lentement du registre de poitrine à celui du fausset ; après quoi, il assouplira le pharynx, et éteindra le son. Je déduis cette règle du fait physiologique que le larynx, étant fixé en bas par le timbre sombre, peut produire les deux registres sans se déplacer. Or, le déplacement entraine le hoquet qui les sépare si désagréablement l'un de l'autre."

[h] *"Elles indiquent à ces derniers la mécanisme à suivre pour augmenter l'étendue du registre de poitrine; elles leur permettent d'employer ce registre piano et à mezza voce dans les notes aiguës et de se dispenser ainsi de l'emploi excessif des sons de fausset ; enfin elles facilitent l'union de registres, etc."* (Garcia 1847a/1985, 58)

[i] "*Llegados a este punto, conviene explicar cuáles eran las bases de esta nueva técnica vocal, llamada romántica, que cambió los esquemas del canto y desterró para siempre a la belcantista. Podemos resumirlas en dos. 1ª) La utilización de una respiración profunda, muy amplia y forzada, costo-diafragmático-abdominal, que permitía una fuerte presión sobre las cuerdas vocales, produciendo y sosteniendo un sonido brillante y de gran potencia. Esto se oponía a la leggerezza di fiato propia del belcantismo, con un tipo respiratorio alto, costo-diafragmático. 2ª) La cobertura de los sonidos agudos, a través del mecanismo de pasaje, es decir, el sombreado u oscurecimiento de la voz, en especial al pasar de la zona media a la alta, que algunos bautizaron como voz negra, que permitió emitir toda la gama aguda a plena voz, sin valerse del falsete, recurso éste al que acudían los belcantistas con su emisión clara. Pero, además, se consiguió estirar la tesitura de las voces hacia arriba, de modo que hubo una conversión de contraltos en mezzo-sopranos, de mezzo-sopranos en sopranos, de bajos en barítonos, y de barítonos en tenores*"

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