

# THE CONTRIBUTION OF CZECH PHONETICS TO LARYNGEAL INVESTIGATION

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## ABSTRACT

Speech has been studied for hundreds of years, but relevant observations often blend with errors due to different biases and the lack of instrumental means. The functioning of the larynx was especially prone to speculation. Before the laryngoscopic era, only excised or artificial larynxes could be studied. Laryngoscopy was founded by J. N. Čermák when he significantly improved the laryngeal mirror. Another development was the use of stroboscopy to examine the vibratory mechanism of the vocal folds in addition to the shapes of the glottis, followed later by high-speed cinematography. The article shows the contribution of Czech researchers to the field, in terms of both methods and findings. It also describes a recently discovered copy of a film from 1928 capturing the activity of the vocal folds.

**Keywords:** larynx, vocal folds, laryngeal mirror, history of phonetics, Czech phonetics.

## 1. INTRODUCTION

It could be argued that phonetics asserted itself as a science in the late nineteenth century, when speech and pronunciation started to be studied systematically and determinedly, as a domain of its own. In addition to the activities of the IPA (founded in 1886), experimental phoneticians like Rousselot began to analyze the stream of speech with the help of a variety of instruments and experimental setups to support direct auditory analysis. However, there is no shortage of observations about pronunciation throughout the centuries before the advent of phonetics. Authors from different backgrounds and with different motivations published, in varying degrees of detail and precision, descriptions of their languages in terms of articulation [14, 28, 23, 19, 16, 35] or later also acoustics [20, 7, 36, 17]. The laryngeal sounds were especially prone to speculation given that the vocal folds and the larynx are hidden from direct visual examination. Even Wolfgang von Kempelen was suggesting that the vocal folds are open during [h] and the fricative noise is due to increased breath [35].

This article presents an overview of how laryngeal activity and the general mechanism of vibration were investigated at different periods. Naturally, only a limited group of researchers can be discussed here. The selection of Czech phoneticians to the exclusion of other nationalities is motivated by (1) a rich history of laryngeal research in the Czech environment, (2) the high impact of some of the researchers on the field in terms of methods, technologies and some specific results and (3) the language advantage of the author, who can communicate not so easily accessible Czech texts to a wider audience. Connections to the European context are discussed only when especially relevant, also partly because the degree of influence due to interactions with other phoneticians was minimal.

## 2. BEFORE LARYNGOSCOPY: J. E. PURKYNĚ (1787–1869)

Jan Evangelista Purkyně was a 19<sup>th</sup> century polymath and especially an esteemed physiologist. His scientific output was extensive and overwhelming, covering all aspects of physiology, from cell theory or heart and brain tissues to sight, hearing and speech organs [18]. Purkyně's early phonetic experiments concern visualization of sound waves and also various hearing-related issues [9, 31]. Crucially, he wrote a book on speech physiology [27], which was presented in 1832 to the Berlin academy of sciences and published several years later in Polish and Czech translation. The book deals with speech organs, the production of speech and its perceptual qualities. Note that it precedes classics such as Brücke's 1856 *Grundzüge der Physiologie* or Bell's 1867 *Visible Speech*.

It can be argued that Purkyně's most significant contribution was perhaps methodological in nature [9, 18]. He conducted experiments and gathered precise observations, from which he inferred about the functions of the organs. He called the method "subjective observation", comprising self-observation and sensual introspection. In terms of speech, Purkyně used proprioception, a mirror to look into the mouth cavity, and also his fingers, which he inserted into the throat to feel the epiglottis and other organs.

We will limit the discussion to Purkyně's treatment of laryngeal sounds. He attributes the qualities of [ɦ], a voiced laryngeal fricative, to the vocal folds and the setting of the larynx. He observes that it is usually bound with the neighbouring vowel, a sort of voiced aspiration (breath), and as such has no specific position of the speech organs above the glottis [27: 95]. It should be stressed that Purkyně had no means to directly observe the shape of the glottis. Yet, thanks to his anatomical knowledge and through proprioceptive feedback in the larynx, he was able to describe the production of laryngeal sounds in substantial detail. As regards the Czech phone, he correctly states that the vocal folds close into vibratory position in the front part, whereas the back part (between the arytenoid cartilages) remains open to allow air pass through the glottis.

Also, Purkyně compared the articulation of the glottal stop [ʔ] to the bilabial plosive [p], as he could hear, at the moment of sudden opening of the vocal folds, a subtle "explosion", just like the lips produce after [p].

### 3. LARYNGOSCOPIC INVESTIGATION: J. N. ČERMÁK (1828–1873)

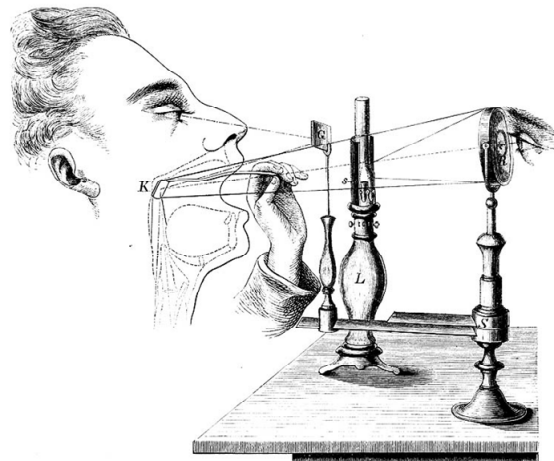
A radical advance in the description of laryngeal sounds could occur after the laryngeal mirror was invented. When Jan Nepomuk Čermák (Czermak), Purkyně's pupil and protégé, started to employ these instruments during his stay at a Vienna physiological laboratory, they had been in use for some time (by García, Türck and others), but the mirror was impractical and considered of no benefit to doctors. Čermák, however, realized the potential. He substantially improved the mirror, its shape and especially the lighting setup (Fig. 1 and 2). It was now possible to use artificial light instead of the unsteady sun, and the procedure was also refined to allow relatively painless examination. Čermák is therefore widely credited with the foundation of a new field, laryngoscopy [8, 29, 1].

Čermák worked hard and published copiously (see his collected works [4]). He constantly travelled around Europe to demonstrate the new instrument and its advantages to doctors, scholars and the public alike. Anybody could look at the vocal folds now (while Čermák was examining himself, another person could be observing as well; see Fig. 2). Čermák studied Arabic speakers so that he would understand the articulation of their "exotic" sounds. But, above all, he re-examined the production of the laryngeal fricatives in order to substantiate Purkyně's subjective findings (see [22]).

**Figure 1:** Čermák's laryngeal mirror [3: 16].



**Figure 2:** Laryngoscopy setup with self-observation and demonstration [3: 99].

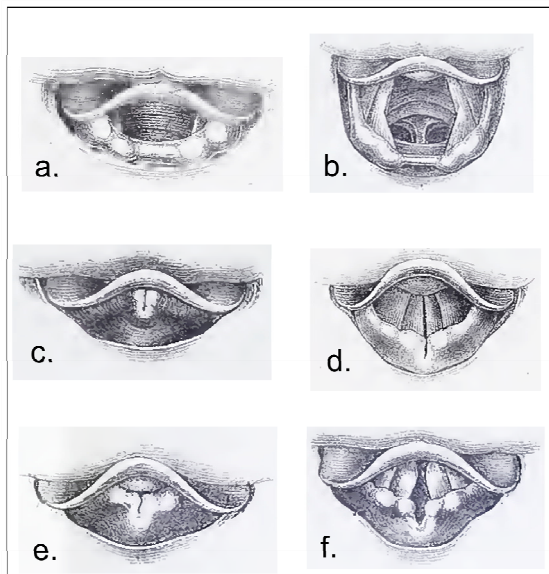


Čermák introduced the laryngoscopic method and its application in physiology and medicine in the book *Der Kehlkopfspiegel* (1860). He minutely described [3: 36-64] what was visible during laryngoscopy of his own larynx. He compared normal and strained breathing (Fig. 3a,b), showed the movement of the arytenoid cartilages and the vocal folds into the phonatory position and the final shape of the glottis, which is different for low and extremely high tones (Fig. 3c,d), and explained how a triple hermetic seal is accomplished through adduction of the vocal folds proper, the false vocal folds and the lowering of the epiglottis (Fig. 3e). His physiological observations were concluded by the description of laryngeal sounds (see Fig. 3f for [ɦ]). The glottal stop is equated with the laryngeal seal.

Phonetically, Čermák's most valuable contribution is a paper discussing specifically the laryngeal sounds. In contrast to Kempelen, he stresses that the fricative [ɦ] is differentiated from breathing and is characterized by an "ordering of the larynx structures" that creates a "narrowing" of the glottis along its whole length, resulting in the "particular friction noise" [6: 751-752]. By manipulating subglottal pressure and width of the glottal opening, we can create a variety of *h*-sounds (not all of them being linguistically relevant). Moreover, if the glottis is narrowed extremely, a strong airflow will cause vibration of the vocal folds. Depending on minuscule adjustments of the laryngeal structures, breathy or normal phonation can arise. The Czech

voiced fricative [f] is a combination of noise and vibration in a special setting: „that part of the outgoing airstream that passes through the [anterior glottis] is set into rhythmical pulsations and a tone arises”, while the part which “passes through the motionless [posterior glottis] instigates a plain friction noise” [6: 757].

**Figure 3:** Shapes of the glottis for normal and intense breathing (a., b.), phonation during low and high tones (c., d.), glottal closure (e.) and glottal fricative (f.). According to Čermák [3: 101].



Unlike Purkyně, Čermák was also immensely interested in the mechanism of phonation. In 1869, he delivered a two-part lecture on “Stimme und Sprache” (“Voice and Speech”) in Jena. Fortunately, it was published among his collected papers [5]. Čermák first talked about the anatomy of the larynx, the shapes of the glottis and the vibratory mechanism, discussing both aerodynamics and muscle activity. Moreover, he demonstrated that pitch depends on tension and length of the vocal folds. He used an artificial and an excised larynx during the lecture (Fig. 4), concluding that “the larynx of a deceased has sung!” [5: 71]. Čermák also noted that as pitch increases, the vibrating part of the glottis gets shorter. He explained that this occurs when the bases (or even the whole length) of the arytenoid cartilages touch, reducing the portion where the vocal folds can vibrate [5: 85].

In addition to discussing ways of voice control, Čermák also differentiates four ways of voice initiation [6]. Aspiration arises when the vocal folds are originally wide open, so that a full tone is briefly preceded by an *h*-coloured sound. An “explosive” beginning occurs when the vocal folds are originally

in the position of a glottal stop. In contrast, after both voiced and (unaspirated) voiceless sounds the vibration starts immediately, without an audible onset. Finally, Čermák considers whisper a different type of voice, in which laryngeal noise replaces vocal fold vibration as the source of sound.

The influence of Purkyně and Čermák is most apparent in Brücke’s work (see [9, 22] for details and evidence in his correspondence). The second edition of Brücke’s *Grundzüge* [2] contains frequent references – every few pages – to their publications and research (Purkyně’s name appears 25 times throughout the book). Crucially, the section on laryngeal sounds is dominated by Čermák (five references); Purkyně is mentioned twice, and two other researchers once.

**Figure 4:** An artificial larynx used in Čermák’s lecture demonstration [5: 71].

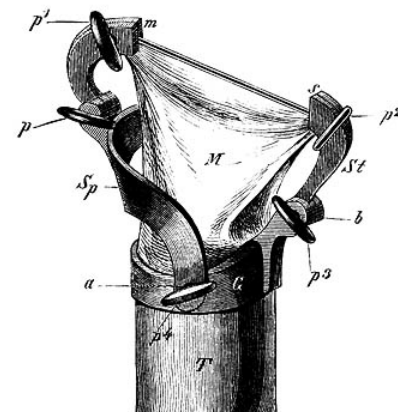


Fig. 27. Künstlicher Kehlkopf.

#### 4. CAPTURING VOCAL FOLDS ON FILM: BOHUSLAV HÁLA (1894–1970)

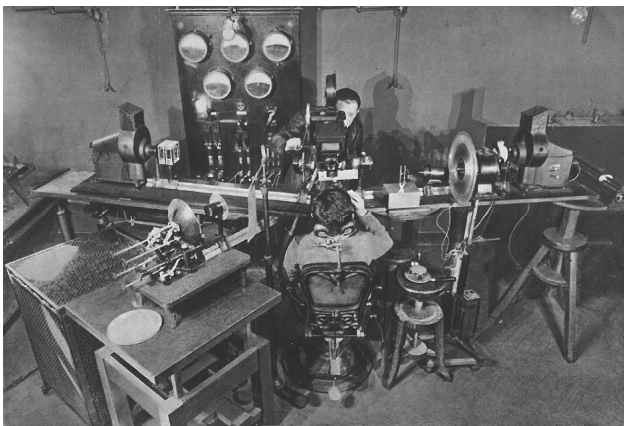
Although laryngoscopy sparked a breakthrough in voice research (and the instrument was among the earliest acquired by Prague’s Institute of Phonetics), the temporal resolution of the human eye was still a limitation. The movements of the vocal folds are too rapid to observe during phonation. As a solution, stroboscopy was applied, for the first time by Oertel [24], to “slow down” the vocal folds in an optical illusion caused by an interrupted source of light synchronized with the fundamental frequency. What is then discerned is a “whole” glottal cycle assembled in fact from different phases of several subsequent cycles [32]. Alternatively, one could capture all vibrations – even irregular ones – by high-speed cinematography (hundreds of frames per second) and then play them back at a slower rate. Both approaches were used by Czech phoneticians.

In 1928, a film capturing the movements of the vocal folds was created by Bohuslav Hála, a

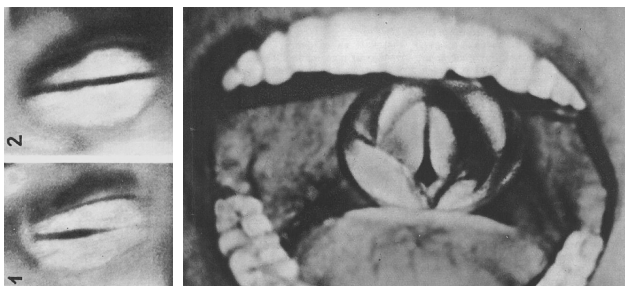
phonetician at Prague's Institute of Phonetics, and his medical collaborator dr. Honty. It was first screened in 1930 at the Fourth International Congress of Logopedics and Phoniatics held in Prague, and at a congress in Germany a year later [10: 14]. The authors also published a detailed description of the procedure along with some results from Czech [11, 12]. They used both stroboscopy (employed previously by Panconzelli-Calzia [15, 26]) and high-speed cinematography (for the first time!). Figure 5 shows the equipment needed.

A well-preserved copy of the film has recently been discovered in the archives of the institute. It was the first work of this kind worldwide, long unsurpassed [25] and the quality of the images – both technically and from a researcher's perspective – is still stunning. The vocal folds are seen in great detail and sharpness. Čermák's static laryngoscopic drawings (see Fig. 3 above) are confirmed, and the film provides new information on the dynamics of phonatory activity. As an illustration, Figure 6 comprises two images taken from the stroboscopic record of Czech [a] and also the depiction of the voiced [fi], which merits special attention.

**Figure 5:** The equipment for high-speed cinematography [11].



**Figure 6:** Two phases from the production of [a] on the left; voiced [fi] on the right [11].



## 5. STROBOSCOPY IN PRACTICE: MILOŠ SOVÁK (1905–1989)

In the 1930s and 1940s, another Czech was investigating the activity of the vocal folds. Although Miloš Sovák, a speech pathologist, was not a member of the Institute of Phonetics, he was Hála's student and later close collaborator (see e.g. their popular book *Voice-Speech-Hearing* [13]) and he lectured on voice hygiene at the faculty. Sovák was a specialist in stroboscopy, using the technique regularly with his patients. Based on twenty years of clinical experience, he published two books that became the standard reading for Czech voice clinicians. One deals with the physiology of vocal fold activity during phonation in normal patients [32], the other with the examination of pathological cases [33]. Both are characterized by a critical discussion of the already extensive literature in the field and by rigorous verification of previous claims through well-controlled direct observation and also through experimentation with excised and artificial laryncs.

## 6. VIDEOKYMOGRAPHY: JAN ŠVEC (1966–)

A recent development was the improvement in high-speed video by Jan Švec and his international team [34, 30]. Their idea was to capture individual vibrations and display them on a screen in real time without slow motion. Only one line is selected in the image of the vocal folds, and it is displayed in a vertical pattern line by line on the screen. In addition, Švec currently conducts research into laryngeal modelling and the mechanisms of phonation [21].

## 7. CONCLUSION

This article presents a brief overview of the contribution of Czech phonetics to the investigation of the larynx and laryngeal activity. After an epoch of anatomical description and experimentation with non-living laryncs, Čermák introduced laryngoscopy into vocal fold examination and elucidated the production of laryngeal sounds. This breakthrough allowed other researchers to utilize direct observation of the vocal folds. In 1928, Hála created the first high-quality cinematographic record of vibrating vocal folds, an unprecedented feat at the time. Last but not least, the interest of Czech researchers in the functioning of the human voice continues until today.

## 8. ACKNOWLEDGEMENTS

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