13.1.4: Singing

The nasal, trachea and lung cavities also add resonances that change the timbre of a person's voice. Some people are gifted with internal air cavities that lead to formants which emphasize frequencies that we find pleasant to listen to; for example a fundamental and several overtones which are exact harmonics. If they are further gifted with (or can train) an ear-brain system that can distinguish frequencies well, they can become a good singer. Training of the voice can improve the range and ability of a singer. Opera sopranos, for example, undergo a long period of training to be able to sing higher notes and to sing loud enough to be heard over the orchestra.

Being heard over the sound of an orchestra seems like an impossible task but opera singers are helped by the fact that the formants involved emphasize many frequencies between 2000 Hz and 3000 Hz. Trained singers create this formant by lowering the larynx and expanding the throat region above the larynx. Orchestral instruments are louder but in a lower frequency range. That plus the fact that humans hear better in the range of frequencies that the voice uses makes it possible for an opera singer to sound as loud as the orchestra without using a microphone (although many performances today do use artificial amplification).

Although the formants used by an opera singer makes the sound more easily heard, they also have an effect on the way certain phonemes sound. The result is that in opera singing, particularly in the higher register of singing, it is harder to distinguish the words being sung. Here are examples of an opera soprano singing scales using a given phoneme. Notice that in the higher pitches it becomes difficult to distinguish different phonemes.

Because there are two or three predominant vocal formants, some singers can emphasize a note and a higher partial at the same time so that they can be heard as distinct tones. This is often called overtone or throat singing. Singers in Mongolia and some other regions use this technique as demonstrated in this video of Mongolian throat singing. About 20 seconds into the video you will hear a whistling sound singing a melody along with a lower drone sound at the same time. Both sounds are coming from the singer's vocal system. This is something that can be learned by almost anyone, as demonstrated by the dozens of YouTube videos on "Tuva Throat Singing".

We know that the speed of sound changes if the density of the medium in which it is traveling changes. We also know that since the speed of sound is related to wavelength and frequency by $v = \lambda f$, changing the speed of a wave will change its frequency (the wavelength remains fixed). You may have heard the voice of someone change when they inhale helium. This occurs because the speed of sound changes and therefore so does the frequency. The effect is as if the formants have shifted upward. Here is a video of a voice with helium and with sulfur hexafluoride. Sound in sulfur hexafluoride is slower so the frequencies of the formant will be lower.

Note

Do *NOT* try this at home. Helium and sulfur hexafluoride do not have oxygen in them and it is possible to suffocate. In particular sulfur hexafluoride is heavier than air and is difficult to get out of the lungs.

Video/audio examples:

- An MRI video of a singing soprano, and the scientific paper that describes why they did it.
- A young girl throat singing "Amazing Grace" (you may have to listen twice to hear the melody).
- An very good explanation of polyphonic singing.
- Recordings and description of Katadjak', a form of Inuit throat singing and voice competition.
- A little science behind "beatboxing". An example without the help of a microphone, Bobby McFerrin.
- What happens to a musical instrument filled with helium or sulfur hexafluoride?