

[DRAFT] My thoughts on breathing, with an emphasis on dealing with chronic shortness of breath

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2024-03-01

Contents

1	Preliminaries	3
1.1	What kind of shortness of breath/air hunger am I talking about?	3
1.2	Why this document?	3
1.3	Warning/disclaimer and disclosures	5
1.4	Ruling out more serious medical problems	5
2	Safety	6
2.1	Accidental meditation	8
2.2	Coughing	9
2.3	Yawning	10
2.4	Breath holds	10
3	The biological basis of shortness of breath	10
3.1	How breathing works	11
3.2	Misconceptions about CO ₂	13
3.3	Chronic overbreathing and the bicarbonate buffer system	13
3.4	The Henderson–Hasselbalch equation and CO ₂ tolerance	15
3.5	Upshot	20
4	Is healthy breathing the same for everyone?/Is normal breathing universal?	20

5 Can you overshoot your CO₂ levels by doing too much reduced breathing?	21
6 A short timeline of my improvements	21
7 Sequence of cumulative constraints of breathing practice	21
7.1 The sequence	22
7.2 Any more stages?	25
8 Clearing your nose	25
9 Techniques vs habits	28
10 Capnometry biofeedback	29
10.1 The unreasonable effectiveness of capnometers	30
10.2 Buteyko community	32
11 Breathing exercises	32
11.1 Main practice: relaxed silent nasal breathing	32
11.2 Introductory exercise: Many small breath holds	36
11.3 Intermittent technique: Double inhale technique	37
11.4 Intermittent technique: Slowing the first part of the exhale . . .	37
11.5 Intermittent technique: watching automatic breaths	37
11.6 Temporary exercise: soft smooth slow long inhales	38
11.7 Temporary exercise: soft long exhales	38
11.8 Intermittent technique: distraction	38
12 Posture	40
13 Breathing synthesis	40
14 Misconceptions	41
Acknowledgments	41
References	42

1 Preliminaries

maybe a better title is: overcoming chronic shortness of breath by fixing your breathing

1.1 What kind of shortness of breath/air hunger am I talking about?

- feeling like you can't get a good breath in
- trying to take forceful breath by e.g. yawning
- some breaths "feel good", other ones (even forceful ones) "feel bad" – there's a binary classification
- no obvious cause: not tied to exercise, seasons, allergen sources, etc.

1.2 Why this document?

there has been a lot written about breathing, both in the academic literature and in self-help/meditation/mindfulness contexts. why am i adding my own words to this vast literature? what value am i adding?

I am writing basically the document I wish someone had handed to me over a decade ago when I first started to experience shortness of breath.

There's a lot written about air hunger already. the problem is that each source only seems to have a part of the solution. there's no one-stop place to get everything i need. so in some sense i'm just synthesizing and collecting everything into one place.

but also, i've noticed a lot of sources making mistakes or not fully explaining things. so i've had to think about some stuff and work it out on my own or with friends, and also by experimenting on my own.

i will be critiquing a lot of sources as i discuss them. i don't want to sound too negative – it's only because of all these sources that i've made significant progress on overcoming my own breathing problem. but seeing how things are explained incorrectly/what can go wrong is one of the best ways to understand why something is the way it is. see here for more on this pedagogical perspective.

note to self: this document should have a tightly focused scope. it's to explain what is going on biologically in air hunger, and then explain *how to get out of that state*. all my other random thoughts about breathing should be

put somewhere else. ask: will this directly help someone who is suffering from shortness of breath?

a note for breathing experts: if you're wondering what the philosophy of this document is in a few words, check out the Breathing synthesis section. In short, my philosophy is the "Buteyko method" + the "Alexander Technique" + capnometry biofeedback, with the first two terms in quotes because I'm sort of doing my own bastardized versions of them, and wouldn't want to claim I am propagating the "real thing". If you don't know what any of the three terms mean, don't worry! They will all be explained in the course of this document.

i think a lot of resources are needlessly general, to the point where the reader has to do a lot of work to figure out which parts to ignore and which parts to follow. trying to satisfy everyone by writing super generally means everyone gets a decent but not great experience. so i'm solving this problem by writing for an extremely specific audience: people like my past self. this will make the document useless or only tangentially relevant to a lot of people, but for the intended audience, it will be *exactly* what they need. i'll try to make this document a self-contained do-it-yourself guide on how to overcome shortness of breath. many other guides don't try to be self-contained; they link out to other things that you can try, or otherwise make you hunt down references or jump through hoops to get them. a printed version of this document, without any internet connection, hopefully with access to a capnometer, and about 2 months (half that if you can already breathe through your nose) should suffice to fix air hunger.

my intention is also not to turn you into some sort of superhuman breathing guru, or cure all your health problems, or whatever. there's only one goal, and it's to completely eliminate air hunger. i think, if you feel inspired by this document and want to go beyond by practicing more advanced buteyko exercises using other sources, that's a fine thing to do! but this document is limited in scope. it only has the modest goal of fixing the air hunger/shortness of breath and doing so in the safest manner possible.

a lot of works are also very wordy and repetitive. this document respects the intelligence of the reader. it emphasizes certain parts to guide the reader, but it will not keep repeating the same things in different words over and over. it will point out common misunderstandings or common misinterpretations, but it will not spend pages upon pages belaboring the point.

1.3 Warning/disclaimer and disclosures

THIS IS A DRAFT. THIS IS NOT PERSONALIZED MEDICAL ADVICE. USE AT YOUR OWN RISK. See the section Safety below for more details. (At the same time, I *am* interested in improving this document, so if you think I am recommending something unsafe or I am making some other sort of error, I'd like to know about it. Email me at riceissa@gmail.com.)

As for disclosures, I have nothing to disclose: I am not selling anything. This document is freely available. I am not affiliated with any of the products or services I recommend in this document. I don't use affiliate links.

also, while i've made significant progress on overcoming shortness of breath, as of this writing i *still experience it daily*. so i think there's still insights i need to discover. but i think i am on the right track in a way that i was *not* before mid-2023, so i think at this point it makes sense to start writing things up and collecting it all in one place, so that as i keep learning i can edit this document. ultimate goal of this document: hopefully in a few months my breathing will be fixed forever and this document will also completely reflect my understanding of how i fixed it.

so yeah, i want to be honest that i haven't figured it all out; i won't pretend i've figured it all out while leaving readers in the dark feeling confused whether they're missing something.

1.4 Ruling out more serious medical problems

If you have the same kind of shortness of breath that I have, then you *do* have a medical problem (this is defended at length in the section The biological basis of shortness of breath), but first, it's good to rule out other more serious medical problems, or medical problems that mainstream medicine knows how to treat.

I think as a first step, it's a good idea to rule out any standard problems with the lungs or other body organs, by e.g., doing a chest x-ray, pulmonary function test, blood test, etc. I will say more about what tests I got done and why. The breathing stuff I describe later in the document *might* help with your breathing anyway, even if you have a problem with your lungs, but you definitely want to know if you do have problems and to get proper treatment for those before progressing to any breathing modification.

<https://youtu.be/G3YHBYVxxmI?t=1049> – Chris Gilbert lists a bunch of possible reasons for hyperventilation that *aren't* just anxiety/stress.

basically, get yourself checked out by one or more doctors, go through the standard protocol, and if the doctors tell you that there's nothing wrong or that your breathing problems are just due to anxiety, *then* come back to this document and try using the methods in it. the only exception i'm aware of so far is asthma. if you have asthma, then supposedly buteyko breathing is also effective, so you can get *both* mainstream medical treatment (e.g., inhalers) and try the things in this document (though i don't have any first- or second-hand experience here so you should probably just go find a buteyko book and follow that instead).

some other possible things that could be going on, where your CO₂ is low but it's not because of a dysfunctional breathing habit: COPD (alveolar and arterial CO₂ mismatch), metabolic acidosis (ketoacidosis, lactic acidosis) (Litchfield and Reamer 2023, p. 29).

see also Box 1.1 ("When is overbreathing acceptable?") in Chaitow, Bradley, and Chris Gilbert (2014, p. 6)

[TODO: add more details]

2 Safety

I want to make two seemingly contradictory remarks about the safety of trying various breathing techniques.

1. Because I am *already* experiencing significant shortness of breath, just by breathing the way I already am, I have a greater appetite/tolerance for air hunger and unsafe breathing. Whether I like it or not, I am already experiencing some significant amount of risk just by existing in my current way.
2. I have the impression that a lot of breathing coaches and such don't emphasize safety enough. One of the reasons I didn't get into Buteyko breathing earlier (despite having known about it since early 2022 or so) is that I was put off by how dangerous it seemed.

When I started practicing silent nasal breathing, I got a few weird symptoms including head pressure, throat tightening (it felt as if I was being subtly choked), and possibly others. (Since I have a mysterious chronic illness, I have a daily occurrence of weird physical symptoms, so I am already quite used to dealing with random new symptoms, and it's often hard to pin down *why* a

new symptom started happening, but in the case of head pressure and throat tightening, I am pretty confident it happens because of the breathing.)

The other thing I want to say about safety. It's not helpful when people just tell you a blanket "if you have health issues, don't attempt this". Part of *why* I'm interested in fixing my breathing is because I already have breathing and other health issues. I shouldn't automatically be turned away from trying to solve these issues! So, I don't want to *ignore* safety issues, but I also don't want to give useless cowardly ass-covering safety warnings. How to avoid both problems?

i also don't want to just put a big safety warning at the start, and then not mention safety at all later on. safety will be a concern throughout. but, also, i will have a safety section here to give an overview of what you might experience.

because i have a lot of health anxiety i am pretty nervous to try new things. i think a lot of buteyko people don't have this same orientation. like, they are in it to get superpowers or something (like sleeping only 2 hours a day) and not out of a sense of desperation to breathe like a normal person. so in some sense this document is like a maximally cautious, "only in it for the health improvements" version.

Andrey Novozhilov (2012) mentions cleansing reactions that can happen, in the section called "Cleansing reactions". Unfortunately it just lists a bunch of pretty nonspecific symptoms without any guidance on what to do about them...

Andrey Novozhilov (2012)'s main suggestion for dealing with problems seems to be "get an expert to coach you". i mean, sure, that's always one solution. but what i'm trying to do here is to write everything down so that one can do all the steps on one's own, as safely and effectively as possible.

buteyko people also mention this, but increased sensitivity to medications can be a thing. i used to (2024-01-07 was last time i took it before breathing changed) be able to take 5–10 drops of methyl factors and it would just give me a bit of energy, but now (2024-01-27) even 1 drop of it seems to send me into irritable/uncomfortable/anxious state. i haven't noticed this kind of heightened sensitivity with any of my other meds/supplements so far though. because the methyl factors thing has only happened once so far (i'm in the middle of the episode as i write this), it *could* be a one-time fluke, who knows.

i tentatively recommend going pretty slowly (need a better descriptor here...) so that you get adjusted to the changes. i'm not sure how to go slowly on some of the steps (e.g., when i switched from loud nasal to silent

nasal, the loud nasal just felt very unnatural so i couldn't go back and titrate it).

if you are already ill in various ways like i am, then maybe it's not a big deal to suffer for a while and make rapid progress. the problem is if it's not *just* being uncomfortable for a while, but if it becomes permanent or if it's a sign of actually dangerous stuff happening. i don't know how to distinguish what each symptom means. hence the recommendation to go slowly.

if done correctly, i think the buteyko relaxed breathing stuff is a lot safer than relying on your own broken instincts about how hard you should breathe. it's only been 2 weeks now since my "breakthrough" on january 15, but i'm noticing a lot less struggle with my breathing, like even the couple of suffocation-like episodes seem milder than some of the stuff i was already experiencing before.

notes from roam:

- one of the things i don't like about buteyko ppl and also litchfield is that they don't emphasize safety enough. . . and like what do you *do* if you start to get intracranial pressure or throat tightening or other weird symptoms?
- this is esp a problem in my case b/c i have other health conditions, and buteyko ppl just do a blanket "if you have health problems, don't do buteyko". that's not helpful.
- and this is esp a problem if like me, you start to just automatically make better breathing a habit – then it's hard to STOP doing it. so what do you do then?

update (2024-02-04): 3 weeks into mostly silent breathing, i am having prolonged (what seems like) electrolyte issues. i can't say for sure that this is from the breathing, as i did eat a quite salty takeout meal (and i've always been sensitive to salty foods), but this is the first time it's lasted 72 hours now (in the past similar things would last at most a few hours).

2.1 Accidental meditation

as you try to normalize your breath, you're constantly paying attention to the way you breathe, and that's essentially the mental motion that meditators make (at least, when they do the kind of meditation where they focus on their breath). could you be accidentally meditating by trying to fix your air hunger?

is that why the intracranial pressure happens? how can we correct the breath without risking accidentally meditating? (most people might have the sense that meditation is harmless, but my current belief is that if you do more than like a few minutes a day, then meditation requires a lot of care to do correctly, and you can really risk hurting yourself/disrupting your whole life. see stuff like “dark night of the soul”. as they say about meditation, “Better not to start. Once started, better to finish.” you really don’t want to accidentally meditate.)

i don’t have any good answers yet. i’m still working through this myself. for the head pressure, it was somewhat bad for one day, but then after that it just got better on its own, and now i don’t notice it at all. i’ve also been just trying to do other stuff, so that even as i do inevitably bring my attention back to my breath to see if i’m still doing silent nasal breathing, i’m not just sitting there doing that the entire day.

Andrey Novozhilov (2012) even says “Exercise 1 is really another version of meditation using the focus on breathing and relaxation of the breathing muscles as the means for avoiding wandering thoughts.”

as of 2024-02-17, i am less concerned about this. i basically don’t notice any changes in my psychological state after focus on my breathing so much. i think as long as you’re doing other stuff in the day, and not just sitting there and thinking about breathing the whole day for hours at a time, you should be fine.

2.2 Coughing

Buteyko people seem too anti-coughing to me. My uninformed guess is that it’s good to cough sometimes, e.g., to clear mucus or during a viral infection. Then there are other more mysterious forms of cough (e.g., twice in my life for like a month each, I had a habit of little micro-coughs/chest itchy feeling) where I think suppressing the cough is more justified (the second time it happened, doing soft breathing to make the cough not trigger is what finally made it go away).

Andrey Novozhilov (2012) says to cough without opening your mouth, but based on personal experience I think this is a bad idea. There can be too much air coming through your nose which can damage the nose tissue. Anyway, this was never a huge issue for me but people with actual asthma might have to adopt different strategies.

2.3 Yawning

I've seen quite often the advice to suppress yawns, but interestingly even the buteyko people say (naturally-occurring) yawning is ok. (Yakovleva, Buteyko, and A.E. Novozhilov 2016, p. 254) I actually agree with this.

2.4 Breath holds

breath holds in general scare me, and i think it's fine if you don't want to do them. really tiny ones (like 1–5 seconds) might be good, just to get yourself used to the idea that not breathing for a few seconds isn't going to kill you (you can even have a pulse oximeter on your finger as you do breath holds, to prove to yourself that your oxygen saturation doesn't drop or only drops an insignificant amount, like 1 percentage point); so i still do include [Many small breath holds] in my suggested exercises. some buteyko books like artour's have more safety information about breath holds.

this is also one of the reasons i prefer Capnometry biofeedback, because it gives you a way to measure progress without taking Control Pauses. (at least initially, until your baseline CO₂ levels reach a normal 40 mmHg.)

3 The biological basis of shortness of breath

I *could* just tell you the exercises you need to do to fix your breathing, but personally I find it unsatisfying when people tell me to do a thing without also telling me why. So in this section, I will give a simplified but (as far as I know) accurate biological explanation of why you have shortness of breath. This will help you understand *why* you should do the particular types of exercises I recommend later on (in Breathing exercises).

If you followed my advice and ruled out serious medical problems with a doctor, you may be thinking there is no biological cause of your shortness of breath, that it is more or less “in your head”. Certainly this is what doctors kept telling *me*, that it was all due to anxiety or some other hard-to-verify physical cause like mast cell activation (primary care physician, two pulmonologists, allergist).

It turns out that there is a pretty well-understood cause of air hunger! But to understand it, we need to have a decent understanding of the chemistry

of respiration; in particular we'll need to correct some misconceptions about breathing. So that's what this section is about.

The aim of this section is to give you a useful mechanistic model of how respiration works. I will skip a lot of details because while it's helpful to know them, they aren't essential.

The central thing we're trying to explain here is: why is it that if you have shortness of breath, the right thing to do is to breathe *less*, even though your body is telling you to breathe *more*? What is going on at the chemical level when people have shortness of breath?

(If you prefer a video instead of text, Cooper (2021) is the best explanation I have found. However there are a few things I don't like about the explanation in that video, so I've written my own version here. But if you prefer a video explanation, then you can start with the video and then come back here. If you do rely on the video, please at least skim Rice (2024) where I explain what I think Cooper gets wrong in his videos.)

3.1 How breathing works

(writing this section from memory; i think if i get anything wrong here, it will be a good thing to point out in the final version!)

How does breathing happen? here is a very simplified sketch:

The mechanical (inspiration and expiration): to inhale, your muscles cause the lungs to expand in volume. As the volume in the lungs increases, the air pressure inside the lungs starts to drop (relative to the baseline of atmospheric pressure), causing air in the atmosphere to enter your lungs, causing pressure to increase back toward atmospheric pressure. To exhale, your muscles *relax* which causes the lungs to contract (the lungs are elastic so they naturally contract); this decrease in volume causes an increase in air pressure (relative to the atmosphere) so some of the air in your lungs leaves. It is also possible to do a forced exhale where the muscles actively contract the lungs in order to push out even more air, but this does not happen in a normal exhale.¹

¹This footnote is intended to prevent a potential misconception. However, the actual details in this footnote are not important for understanding the rest of the document, so I've decided to not include it in the main text. Those with knowledge of chemistry will remember the ideal gas law, $PV = nRT$, which relates the pressure P , volume V , amount of substance n , and temperature T of a gas, with some constant R that varies depending on the units.

If we try to model the lungs naively based on this equation, we run into trouble. Let's see how that happens. During the exhale, the lungs contract by let's say 20%, i.e., its volume

The chemical: at the very edges of your lungs are tiny sacs called alveoli. the alveoli are surrounded by capillaries, and this is where gas exchange takes place. when air from the atmosphere arrives at the alveoli during inhalation, there is more oxygen in the atmosphere air, so the oxygen diffuses into the capillaries. At the same time, there is more carbon dioxide in the capillaries, so that diffuses back into the alveoli and then out into the atmosphere. this two-way diffusion is just happening all the time continuously, and inhalation and exhalation just bring or pump out the air so that more diffusion can take place. This two-way diffusion happening at the lungs is called **external respiration**. The oxygenated blood then moves through your body and goes out to all of your cells. At your cells, the blood has oxygen and your cells have carbon dioxide, so another exchange takes place, called **internal respiration**. Finally, all the while your cells are using up the oxygen to produce more carbon dioxide in a process called **cellular respiration**.

The neural: What causes the urge to breathe? Humans have what are called chemoreceptors in their brain (and some other places) that tell the body to breathe. How do chemoreceptors know *when* to send the signal to breathe? Do they just have a timer in them and send a signal every few seconds? It turns out that they watch out for signals from the body, in the form of carbon dioxide levels, oxygen levels, and blood pH. Most of the time, when people breathe, it is because the carbon dioxide level increased above some threshold. Oxygen only triggers breathing when it gets really low (so low that I don't think most humans experience it except on very rare occasions). I think blood pH also matters, but maybe only during exercise? (but it might matter more for people with air hunger; see below).

Notice how the three aspects interact: the mechanical action allows the

changes by a factor of $1 - 0.2 = 4/5$. To make up for this decrease in volume, now pressure must increase by a factor of $5/4$, i.e., the pressure increases by $5/4 - 1 = 25\%$. The increased pressure then expels the air, so n goes down, which then makes P go down again.

The problem is, when actually measured, the pressure in the lungs increases by only about 1 mmHg from a baseline of 760 mmHg (the atmospheric pressure), so the pressure in reality only increases by about $761/760 - 1 \approx 0.13\%$, not 25%. Why the huge discrepancy? It is because the exhalation does not happen in a rigid sequence like “the lungs contract all at once; the air pressure is raised; the air flows out to neutralize the pressure difference”. Instead, as the lungs begin to contract, the air starts spilling out almost immediately, so as the pressure starts to build up from the contraction, pressure also starts to neutralize from the air escaping the lungs. So the actual pressure increase during exhalation cannot be calculated solely from the contraction in volume; it's instead coming from the *lag* from when the lungs begin to contract and when the air starts to leak out.

chemical exchange to take place (without just being stagnant at some dynamic equilibrium). The chemical process is what stimulates the nervous system. And the nervous system sends a signal to the mechanical part to make the motions.

3.2 Misconceptions about CO₂

From the above description, and based on your pre-existing knowledge, you might have the impression that CO₂ is just a waste product. but actually, both too-low and too-high CO₂ cause problems for the body. [TODO: say more]

i'm not very attached to "high levels of CO₂ are super healthy". i honestly haven't vetted the claims. but basically everyone (including mainstream western medicine) agrees that 35–45 mmHg is the healthy range for partial pressure of CO₂.

3.3 Chronic overbreathing and the bicarbonate buffer system

acid–base balance, bicarbonate buffer model (also called "renal compensation", e.g., see https://en.wikipedia.org/wiki/Renal_compensation and <https://youtu.be/G3YHBYVxxmI?t=1527>)

mention how people with shortness of breath might not think they are hyperventilating. For example I don't think I've ever overtly hyperventilated in my life. And yet, I was constantly low-grade overbreathing. Chris Gilbert (2014, p. 68) says "Hyperventilation tends to persist in many people, and once a pattern of overbreathing is established it can be maintained by only a 10% increase in minute volume, which could be achieved by a combination of deeper breaths, faster breathing, or an occasional sigh". Chaitow, Bradley, and Christopher Gilbert (2002, p. 246) is also great and I wish someone had pointed me to it because I kept thinking "there's no way I'm hyperventilating, I sure am not acting like how it is portrayed in media"; I have no idea why they removed it in the second edition of the book. However, I think their list of criteria for detecting overbreathing are not great. In particular, if you're nose breathing but your breathing is clearly audible, then I think that's a sign of overbreathing.

kidneys are supposed to adjust within 5 days. BUT mine seem to be taking a lot longer (it's been about 2 weeks of normal baseline CO₂ according to capnometer now as of 2024-01-31, and i'm still having air hunger daily). why

could this be?

- it's possible that with my dysautonomia (and/or whatever else is wrong with me) my kidneys are just not NORMAL kidneys, but sluggish broken kidneys
- i also have an inkling that the studies they did on this was for ppl who overbreathed during the experiment, not ppl who have been overbreathing for literally over 10 years. it's possible (just like with SSRIs or various other medications or w/e) that if you've been overbreathing for much longer, then your kidneys are just "more stuck", "more set in their ways", than the standard experimentally verified number. if true, now that i am at a normal CO₂ baseline, i should just be able to literally keep going, keep doing the same thing, and the air hunger should just gradually disappear.
- maybe my bicarbonate levels take 3–5 days to adjust to one additional "rung", and there are like several rungs? i am not quite sure how that would be, but this could be why it's taking way longer than 5 days. (and experiments maybe only tested a "one-rung change".) It would make sense that making a greater change takes a longer time.
- the literature could just straight up be *wrong* about this, like, on what experimental or theoretical basis are they even claiming the kidneys take 5 days? i have not looked into the actual experiments so i can't tell whether people are just parroting flawed studies or the experiments were replicated.
- the other idea is that my CO₂ is totally normal now when I measure during the day, but somehow, somewhere, I'm still overbreathing. Maybe in my sleep, maybe in small pockets of time when I'm stressed, maybe whenever I talk. And that little bit of overbreathing is preventing the bicarbonate levels from fully adjusting. Hence why I still feel subtle air hunger.
- Vipul notes that the literature may be basing kidney adjustments partly on mountain climbers ("altitude acclimatization") who are adjusting to low CO₂ so are shedding more bicarbonate rather than in the case of overbreathers who are trying to gain back their bicarbonate. Mountain climbers are also adjusting to lower O₂, not just CO₂. So it's possible that what happens to them is just quite different from what happens to chronic overbreathers.

I don't know why no one seems to ever talk about this, but there are literal

blood and urine tests to measure bicarbonate levels (it's called "total carbon dioxide", and is included in the comprehensive metabolic panel, which is a pretty common test. Total CO_2 includes not just bicarbonate but also the dissolved CO_2 in blood and the CO_2 carried by hemoglobin or something, but the bicarbonate makes up most of the total carbon dioxide. However, I am still confused about how to interpret the results of this test). In the US at least, if you have a good insurance or Medicaid or something, then (assuming you can convince a doctor to order the test) this seems like a *way* cheaper way to see if you have hypocapnia, although it won't really allow you to do real-time biofeedback like with a capnometer. (Update(2024-02-07): this turned out to be WRONG. My total CO_2 has been normal this whole time despite my end-tidal CO_2 being low. So getting a normal level on the total CO_2 test does not actually rule out hypocapnia.) I think these blood/urine tests might also be very helpful in intermediate stages of recovery (like where I am at now as of 2024-02-02) where my CO_2 levels are normal according to the capnometer but I still have that subtle feeling of air hunger. (Update(2024-02-07): I am no longer so sure about this... I think the total carbon dioxide test might be useless.)

I have not tried this, but it is possible to *supplement* bicarbonate in addition to changing breathing habits, which might speed up progress: "Long-distance runners, sprinters and horse trainers have experimented successfully with doses of sodium bicarbonate, which supplements the natural bicarbonate buffer and opposes the lactic acid load created by exercising muscles" (Chris Gilbert 2014, p. 66) <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC435634/pdf/jcinvest00601-0100.pdf> ("STUDIES ON HYPERVENTILATION. II. ELECTROCARDIOGRAPHIC CHANGES IN NORMAL MAN DURING VOLUNTARY HYPERVENTILATION" by B. CHR. CHRISTENSEN) also mentions an experiment to give large doses of sodium bicarbonate to subjects to generate (!) a feeling of air hunger. more bicarbonate mimics the effects of less CO_2 . so maybe supplementing bicarbonate isn't the solution.

3.4 The Henderson–Hasselbalch equation and CO_2 tolerance

[argh, this is kind of hard to explain well. curse of knowledge...]

Okay, so CO_2 levels (partial pressure?) in the blood regulate breathing. Now let's imagine what happens when someone overbreathes. You might

think, okay, CO_2 goes down, so then you don't get as much of an urge to breathe. That's true in the short term. But if someone *chronically* overbreathes, then the bodies tries to correct this. You see, the body tries very hard to keep the blood pH at a narrow range of 7.35–7.45. If one chronically overbreathes, then since CO_2 causes the blood to become acidic, the *lack* of CO_2 (you're overbreathing, remember) causes your blood to become too alkaline. So the body compensates by trying to make blood more acidic. How? The kidneys dump out more bicarbonate (HCO_3^-) into the urine. Since bicarbonate is alkaline, getting rid of it makes the blood more acidic. The kidneys don't react immediately; all this happens over the course of hours to roughly 5 days.

[... some more stuff here ...]

The important point is that because of the form of the Henderson–Hasselbalch equation, the more CO_2 you have, the less sensitive pH is to slight increases in CO_2 . So breath holding for a few seconds does not cause air hunger/panic/suffocation. Whereas if your CO_2 is already too low (hypocapnia), then your pH is still normal (thanks to the bicarbonate levels being adjusted by your kidneys), but because of the low CO_2 , even slight changes in CO_2 can cause large shifts in pH. I think it's this decrease in pH (when CO_2 rises, blood becomes more acidic so pH goes down) that triggers a strong sense of air hunger. If you give in to this urge and breathe, then your pH will be restored, so *temporarily* you will feel better. But if you keep giving into this urge and breathing more and more, then over time you're shifting down your bicarbonate buffer even more. Your body adjusts. But that means your baseline CO_2 also keeps decreasing. So now you're *even more* sensitive to slight increases in CO_2 . It's a vicious cycle. (and this isn't even talking about the negative health effects of low CO_2 .)

Let's look at some numbers.

$$7.4 \approx 6.1 + \log_{10} \left(\frac{24}{0.0307 \cdot 40} \right)$$

above are the values for a normal person.

When I first used a capnometer, my CO_2 was around 25 mmHg. So to get the same pH, my bicarbonate level must have been around 15 (here I'm just solving for x in the equation $24/40 = x/25$ in order to make the input to \log_{10} the same):

$$7.4 \approx 6.1 + \log_{10} \left(\frac{15}{0.0307 \cdot 25} \right)$$

Now let's say both individuals do a breath hold to raise their PCO_2 by 5 mmHg. In the case of the healthy person, their pH goes down to 7.34, but in the chronic overbreather's case, it goes down to 7.31.

here's the other thing vipul showed me:

suppose your equation right now is:

$$\begin{aligned}\text{pH} &\approx 6.1 + \log_{10} \left(\frac{[\text{HCO}_3^-]}{0.0307 \cdot p\text{CO}_2} \right) \\ &= 6.1 + \log_{10}([\text{HCO}_3^-]) - \log_{10}(0.0307) - \log_{10}(p\text{CO}_2)\end{aligned}$$

Now you hold your breath so that the $p\text{CO}_2$ goes up by some amount, $\Delta p\text{CO}_2$, and the pH changes by some amount, ΔpH (it's a negative quantity, since your pH goes down when the blood becomes more acidic). Your equation now looks like:

$$\begin{aligned}\text{pH} + \Delta\text{pH} &\approx 6.1 + \log_{10} \left(\frac{[\text{HCO}_3^-]}{0.0307 \cdot (p\text{CO}_2 + \Delta p\text{CO}_2)} \right) \\ &= 6.1 + \log_{10}([\text{HCO}_3^-]) - \log_{10}(0.0307) - \log_{10}(p\text{CO}_2 + \Delta p\text{CO}_2)\end{aligned}$$

Now let's subtract the first equation from the second; we get:

$$\begin{aligned}\Delta\text{pH} &= \log_{10}(p\text{CO}_2) - \log_{10}(p\text{CO}_2 + \Delta p\text{CO}_2) \\ &= \log_{10} \left(\frac{p\text{CO}_2}{p\text{CO}_2 + \Delta p\text{CO}_2} \right) \\ &= -\log_{10} \left(1 + \frac{\Delta p\text{CO}_2}{p\text{CO}_2} \right)\end{aligned}$$

What does all of this show? Well, the quantity $\frac{\Delta p\text{CO}_2}{p\text{CO}_2}$ is actually the fractional change in $p\text{CO}_2$. So it shows that *the change in pH is a function of the fractional change in $p\text{CO}_2$* . This is one way to understand why having low CO_2 means your pH changes more easily: the same amount of absolute CO_2 change results in a greater fractional change in CO_2 . (Note: fractional change is almost the same thing as percentage change, just divided by 100.)

Here's a model you can play around with in Python:

```
from math import log10

# These two values are obtained from measurements
```

```

etco2 = 35 # This comes from the capnometer
total_co2 = 28 # This comes from the "total carbon dioxide"
               # blood test

# Arterial pCO2 is typically a little bit higher than the
# end-tidal pCO2. Here we just guess it to be 5 mmHg higher.
paco2 = etco2 + 5

carbonic_acid = 0.0307 * paco2

# total CO2 = bicarbonate +
#             CO2 as carbonic acid +
#             CO2 in hemoglobin (estimated to be 10% of the
#                               total CO2)
# So we are just solving for the bicarbonate term:
bicarb = 0.9 * total_co2 - carbonic_acid

# This is the Henderson-Hasselbach equation for pH
pH = 6.1 + log10(bicarb / carbonic_acid)

print(pH)

```

This seems wrong to me, but I should look at the cited works by Ley: “Ley (1988a, 1988b) has offered a plausible explanation for this phenomenon based on the body’s adaptation to chronic hyperventilation. The long-term reduction in bicarbonate buffer concentration, offsetting lowered PaCO₂, returns pH to normal, but the equilibrium is an uneasy one, dependent on the hyperventilation continuing. This situation makes the individual more susceptible than ever to a rise in CO₂ (more acidity) because the alkaline buffer has been reduced. Consequently a change in breathing toward normal, away from hyperventilation, would feel closer to suffocation than if the person possessed normal bicarbonate buffering capacity.” (Chris Gilbert 2014, pp. 68–69) Specifically, i don’t think it’s the lower bicarbonate that is the problem, it’s the lowered CO₂. i think the literature is very misleading about this point and they all keep repeating the same mistaken thing, and none of them actually provide a mathematical model of this. In more detail: The specific sentence I am critiquing is: “This situation makes the individual more susceptible than ever to a rise in CO₂ (more acidity) because the alkaline buffer has been reduced.” In the HH

equation, the bicarb concentration is a constant because the rise in CO₂ being mentioned here is an acute one. The things that are changing are the CO₂ and pH, and the reason the pH changes more is because the CO₂ is already low. The reason the CO₂ is low is because the person chronically overbreathed. The reason the CO₂ *remains* low is because the bicarbonate level also changed. But you see how that's like, several levels of indirection until we even get to the bicarb. Saying the word "because" followed by the bicarb/alkaline buffer makes it seem like that's the direct/primary reason, but in reality it's instead just this thing in the background that is keeping up the equilibrium. However, I do admit the author here may have had the correct model and was just wording it poorly.

"Thus the chronic hyperventilator's pH regulation is finely balanced: diminished acid (the consequence of hyperventilation) is balanced against the low level of blood bicarbonate maintained by renal excretion. In this equilibrium small amounts of over-breathing induced by emotion can cause large falls of carbon dioxide (PCO₂) and, consequently, more severe symptoms. In other words, the chronic hyperventilator lives closer to the threshold for hypocapnia than the normal person." https://web.archive.org/web/20230127113032/https://buteykoclinic.com/docs/hyperventilation%2Ba%2Btherapists%2Bpoint%2Bof%2Bview_1401456256.pdf – another example of a paper seemingly getting this wrong.

for advanced buteyko practitioners however, my current guess is that their PCO₂ levels are normal (40–45 mmHg). so now, how do we explain how they can hold their breaths for so long? i think some other factors are at play here including:

- less sensitive chemoreceptors
- hemoglobin count or efficiency
- myoglobin count or efficiency
- reduced or more efficient cellular metabolism (slower rate of generation of CO₂)
- higher lung capacity

some of the above may also be happening in going from chronic over-breather to normal breather, but it's not obviously necessary to explain the differences in CO₂ tolerance between overbreather and normal.

3.5 Upshot

So what we've established is:

- If you have shortness of breath with no clear medical cause, it is likely that your CO₂ level (and thus bicarbonate level) is too low.
- Low CO₂ means you are more sensitive to changes in CO₂, in particular to increases in it. This is why you always feel short of breath.
- The solution is *not* to “take a deep breath” and get more oxygen (you already have plenty of oxygen, probably too much, as can be verified easily with a pulse oximeter), but rather, to breathe *less* so that you *gradually* raise your CO₂ levels. The emphasis is on the word “gradually”. If you just hold your breath as long as possible in the hopes of raising your CO₂, you will just give yourself a panic attack. The kidneys take time to adjust the bicarbonate levels. So you want to sit with a slight-to-moderate amount of air hunger, over the course of days and weeks, so as to gradually raise your baseline CO₂. How to do this? We'll discuss breathing techniques and breathing habits more elsewhere in this document (see the sections Techniques vs habits and Breathing exercises).

4 Is healthy breathing the same for everyone?/Is normal breathing universal?

One of the weird things I discovered while using the CapnoTrainer is that the breathing style that brought CO₂ levels up to normal in the most effortless way turned out to be what the Buteyko people have been saying all along: silent nasal breathing. This raises the question of whether there is some universally “optimal” breathing style that everyone should have, or if it's more of a preference (different people can have different breathing styles, but what matters is that your CO₂ levels are normal and you don't have air hunger or other breathing issues).

Peter Litchfield on the other hand says that it doesn't matter how you breathe – you could even mouth breathe – as long as your breathing habits are “functional” (by which I think he means your CO₂ levels are at like 40 mmHg). For example see Litchfield and Reamer (2023, p. 21), where “There is an ideal breathing pattern that each of us needs to learn” is listed as a misconception.

5 Can you overshoot your CO₂ levels by doing too much reduced breathing?

so you combat air hunger by breathing less, which raises CO₂. what if you just keep going? could you be overshooting and getting *hypercapnia* instead?

Here's a heuristic argument for why this shouldn't happen: even people who overbreathe don't overbreathe so much that their CO₂ just keeps dropping indefinitely. Each style of breathing seems to asymptote at a certain point. So I think Buteyko-style reduced breathing also asymptotes in terms of CO₂ levels.

But also, I think there must be some other effect going on, because I don't think the Buteyko people have abnormally high CO₂ (that's just my current guess). the only source i've found so far is the graphs in Altukhov (2009) where the highest tier (tier V) under "Super Endurance" has an alveolar CO₂ of 54 mmHg. But they also list "normal" as being 46 mmHg which seems too high...

the main lesson here is that having a capnometer is quite useful, to give the assurance that your CO₂ levels are normal.

6 A short timeline of my improvements

i don't know how representative the speed of my improvements is, but it's the only case i am deeply familiar with, and it might give people an idea of what to expect.

[TODO: add this]

7 Sequence of cumulative constraints of breathing practice

We are now transitioning to the more practical sections of this document. But before we get to the actual exercises, I want to say a few things about the mindset/global structure of the practice.

I think it may be helpful to conceptualize breathing practice² not as a set of "breathing techniques" that you practice over time to help calm you down or

²By "breathing practice", here I specifically mean breathing practice to cure shortness of breath from over-breathing, but it may also apply to meditative practices as well, I don't know.

whatever (such as: “when you’re feeling anxious, do square breathing; once you feel comfortable with that, you can move onto different patterns like 4-7-8”), but instead as a *sequence of cumulative constraints*. The reason for having a *sequence* is that it’s too hard to pay attention to the more subtle stuff and get it right all on the first try before you get the basics down; each stage might take a month or more. (The other reason for this particular sequence: if you follow the sequence, then by doing the previous steps, you automatically almost do the next stage, so that at each stage you only need to put in a *little* bit of effort, not invent a whole new thing.) The reason for having *constraints* rather than practices is that it mostly doesn’t matter *how* you achieve good breathing, you just want the outcome.

This page used to use the phrase “sequence of moving targets” rather than “sequence of cumulative constraints”, but I renamed this page because I thought the new version is a more accurate phrasing. Like the Gram–Schmidt process in linear algebra the constraints are cumulative (at each step n , you want to make sure that the new vector you create is orthogonal not just to the $(n - 1)$ th vector, but to *all* the vectors $1, \dots, n - 1$. This kind of mechanic also happens a lot in puzzle games where if you get one thing in a “good” state, and then try to get another thing in a “good” state, the first one will turn back into a “bad” state, and the difficulty of the puzzle is to make sure you can get all the good states cumulatively). Also “constraint” feels more accurate than “target” because you’re not trying to hit some new breathing pattern some of the time, but rather you’re trying to *only* do the “good” kind of breathing *all* of the time.

7.1 The sequence

Here is the sequence I am thinking of:

1. Initially, because I was still mouth-breathing a significant percentage of the time (20%?), my constraint was to do nasal breathing. *Any* nasal breathing. The goal was simply to get away from the habit of mouth breathing. Nasal breathing is a good first target because (a) it’s extremely obvious whether any particular breath happens through the nose or mouth; and (b) on its own it already has pretty dramatic effects (see Nestor (2020) for a lot more detail on this). Achieving nose breathing itself occurs in two stages:

- Consciously do nasal breathing. You use any and all tools you have to try to nose breathe: just anxiously paying attention all the time, nasal strips, nose cones, azelastine, NeilMed, allergy sheets, etc. (Flonase is another option that *might* help people but it didn't work for me because of side-effects and there's a chance it builds up a dependence even though it's not supposed to?) You want to get to a point where the only times you mouth breathe are when you have to blow your nose, when you swim, when you take a shower, or things like that. I nose breathe even with a mask on, even when I'm brushing my teeth, and as much as possible even in my sleep (mouth taping might help with this). (This step took around 1 month for me.)
- Eventually, it becomes automatic, and you won't even need the training wheels. (After a month, my nasal breathing became habitual/automatic. I remained at this stage for the next 4 months or so, not because I wanted to but because I wasn't sure what to do next.)

2. Next stage: silence your breath.

- Same two stages here (conscious/manual techniques, then unconscious/automatic habit). Silent breath is the next constraint because it's also easy to detect: it means you can't hear your own breath at all (neither inhale nor exhale). Silent breath. At least when you're just sitting or standing. I'm not sure how feasible it is yet to have a silent breath while exercising. (This stage took about a week once I got the CapnoTrainer, though arguably it's still ongoing. In particular, there was a 24 hour period where I had a kind of epiphany and figured out how to do this right.)
- As with the nose breathing stage, you don't have to get it to be perfect. Sometimes, breathing in a silent way can make your diaphragm or your throat hurt. I think this happens because you're manually trying to control those muscles too hard by tensing them up in the wrong ways. If that's the case, you can try for a while to just make a bit of noise when breathing, just like you might still have "rescue breaths" through your mouth sometimes.
- Eventually, given a choice between silent vs natural, you want to pick natural, but still silent is the initial target because it's so much easier to tell when something is silent vs natural.

3. Next stage: smooth your breath.

- Even when your breath is through the nose and silent, it can be “jagged” on the CapnoTrainer. It can even *feel* jagged to you, like you’re manually forcing air out in little bursts, instead of it just flowing out like it should. I don’t know how to fix this one yet, but it seems harder to notice and harder to fix, so that’s why it comes later. But the idea, at least for the exhale, is to just try to let go of the breath and naturally let your diaphragm relax. It should feel like your body is just relaxing, instead of exhaling (even though of course you are also exhaling). As I said, I’m still experimenting with this one.
- This one is tricky because I notice that as I try to do it my diaphragm can get sore if I do it wrong. In particular, it can sometimes help to break the “silent” rule in order to get the breath smoother. There’s a distinction between breathing in a way so that you aren’t hypocapnic, and breathing in a way that is comfortable and not painful to your body. Every combination is possible.

4. Next stage: slow down your breath.

- Your breath should already be slower if it’s more quiet and smooth. But when you’re trying to make it quiet or smooth, you don’t want to focus on slowing it down ... that just makes you uncomfortable because you’re not used to that much air hunger. But once your breath is silent and smooth, it’s time to focus on slowing it down. I still haven’t gotten to this stage so I don’t know how slow is optimal. I suspect this is the point where an HRV monitor or such would be handy: there might be individual variation in the optimal rate. Notice how it’s much harder to say what “slow breath” is compared to “nasal breath” or “silent breath” or “smooth breath”, and it is much harder to track without an instrument like a capnometer (counting in your head all the time seems annoying!).
- UPDATE (2024-01-26): i am thinking more and more that slowing your breath is unnecessary; it’s like the diaphragm thing and it automatically happens. i think some of the buteyko people also say the same thing. e.g. see Andrey Novozhilov (2012); in the section “Approach 3 – Just hint at reduction of airflow” there is an illustration of a snake where slowing down the breath is a sign of doing the ex-

ercise wrong. Under mistakes, he lists “Increasing the frequency of your breathing or changing the length of inhalation or exhalation.”

Note that the above is essentially (some of the particular techniques taught in) Buteyko breathing. The differences are: (1) pedagogical, in that I think focusing on each step in sequence works a lot better, and (2) whether to use a CapnoTrainer to help with some of the steps.

7.2 Any more stages?

i have a feeling that the final stage (beyond the ones i listed in the previous section) is “exercise while doing all of the previous ones”. this is explicitly part of some buteyko guides. vipul also (i think independently) recommended i do this.

upper chest (intercostals) vs diaphragm? i feel like this one happens automatically by doing the ones above. But for some reason this is like the focus of many breathing gurus/meditation experts. but it’s not necessary! in fact, i think it can be harmful to focus on your diaphragm too much – it leads to exaggerated/forceful movement of it which can cause overbreathing/sore muscles. like, sure, it’s fine to check your abdomen to see that you are generally breathing with your diaphragm more than upper chest, but it shouldn’t be a target.

8 Clearing your nose

In my view, nasal breathing is essential for overcoming shortness of breath. It’s also the very first step. There’s a lot of strategies here so I’ll list a bunch along with what I think of them. My guess is that different ones will work for different people, so you kind of want to try a bunch and see what works (most of these are quite cheap).

I won’t say much about *why* it’s better to breathe through your nose, as I think this is already covered pretty well in other sources, in particular Nestor (2020), which gives a pretty vivid description of the author’s own experiment of breathing solely through his mouth (it’s scattered throughout the book, so unfortunately I can’t cite a specific chapter).

I think there are two broad ways you can react to “you need to clear your nose”. One of them will be to say “Yeah, I hardly ever breathe through my nose; I know I need to work on it but I don’t know how”. The other is to say

“I already breathe through my nose; I don’t think I need any advice”. For this second type of person I want to mention my own anecdote. Before I started really focusing on my breath, I used to think I was already a nasal breather, but when I started paying attention I realized that I was actually taking quite a few mouth breaths throughout the day. A sure way to find out is to tape your mouth during the day (even for just 15 minutes or so) and see how easy it is for you. I think I probably went from around 80% nose breaths to 99.9% nose breaths by following the strategies listed below (just a wild guess unfortunately because I didn’t keep good records); during breathing attacks, I probably went from 10–50% nose breaths to 95% nose breaths. So if you already think you are a nasal breather, I would still try paying attention.

Here are the main strategies I recommend for clearing your nose so you can nose breathe more:

- Saline spray: works less well than the saline wash, but it’s a lot less unpleasant. it doesn’t go “deep” enough, which is why it is both less painful and doesn’t work as well. i went through about 1.5 bottles of the NeilMed one (lime green color bottle) before my nose improved enough that I didn’t need to use it anymore.
- Saline wash/netipot: tried this once. it works really well for clearing your nose, but it was also quite unpleasant. make sure to never use tap water for this.
- Nose strips: these were quite helpful. at first i used the RiteAid brand ones and they worked well enough, and then i got cheaper ones from Amazon and those also worked fine. so my guess is that there isn’t much of a quality difference between different brands, and you can just go with whatever. the main thing to watch for is that your skin should not get irritated from using them. also, you should *immediately* notice an improvement. if you don’t immediately breathe better, then you’re either not putting them on right or the thing isn’t working. There is also a magnetic strip made by a company called Intake Breathing. I never used it so I don’t know how well it works, but if you can’t get regular nose strips to work, you can look into this.
- Nose cones: these didn’t work for me (i got them because i was encouraged by how useful the nose strips were, and cones seemed like reusable strips). they don’t go deep enough in the nose, so they really only help i think if you have a deviated septum or something. . .
- Patrick McKeown’s nose unblocking exercise: this is one where you pinch

your nose while holding your breath, and swaying or walking around as you do that. I tried this back when my nose was stuffier, and it didn't work very well for me, but i also didn't try very hard to get it working (i just followed one of his videos).

- Antihistamine spray (e.g., azelastine): my guess is azelastine did nothing for me. but maybe it helped a bit with reducing mucus producing during the night. i never tried olopatadine (the more famous antihistamine nasal spray) because my insurance doesn't cover it.
- Steroid spray (e.g. Flonase): i would stay away from these, unless you already know they work well for you. definitely try all the other ones in the list first. note that there are different kinds of steroid sprays and some of them are *very* bad to keep using long-term. Flonase is supposed to be one of the safer kinds, but i only used it once so i can't speak to any longer-term effects.

Important note: as you start breathing through your nose more, you should find that your nose becomes less blocked even without doing these things. I used to need the nose strips *a lot* when I first started nasal breathing. But now I hardly need them. So these techniques should be thought of as temporary crutches – or like training wheels on a bicycle. They are there to help jump start your nasal breathing until your nose is strong enough, but you shouldn't need them forever. I had a clear shift when I first switched to nasal breathing, and then a second shift when I switched to *silent* nasal breathing. It seems odd that my nose would clear up with *less* air moving through the nose. My hypothesis is that either my health in general got better, or maybe less air means less irritation. Lippmann (2015) mentions that “the thickness or thinness or real-time mucous production, as well as nasal turbinate size are regulated by CO2 levels”, so that's another possible thing that maybe happened to me.

Definitely don't get surgery, unless you've tried all the safe options and nothing works. I think the mainstream medical world understates the risks here, e.g., you should at bare minimum know about empty nose syndrome. Nestor (2020, chapter 7) has a bit about this. See also Sager (2024) for a random encouraging anecdote that I came across on Twitter.

i should say something about mouth taping as well. i don't have any *strong* argument again it, but i have personally not done it (except for briefly during the day). as you improve your breathing, your mouth should automatically close. so mouth taping is, in my view, unnecessary in the long-term. what about the short term? after all, all the other nose-unblocking stuff i'm recom-

mending are short-term crutches as well. i think in the short term maybe it's completely fine? i was just personally scared of using it, and never needed it. waking up in the middle of the night gasping for air is pretty horrible (i've had it happen in the past even without mouth taping).

my nose still sometimes feels blocked in the morning. not sure what's going on there, but i have a guess that the reason my one nostril plugs up during the night is actually functional. breathing needs are reduced during sleep because you're just lying there and using no muscles. so even the quiet gentle breathing style i have going during the day would be too *much* air. so my body figures out a way to reduce the air flow, which is to block out the one nostril. this is why my nostril is plugged up, but i seem to be breathing solely through the nose the whole night, even if things are blocked! *and* it's also why as soon as i wake up, the mucus clears up, because my body realizes "wait, now i'm awake and upright and active, and this is too *little* air now, we must unblock the nostril!" So for a few moments in the morning i feel a little uncomfortable and might have to take a few forceful nose breaths or even sometimes mouth breaths, but then my body adjusts within 30 minutes to an hour and i'm ok again.

9 Techniques vs habits

One of the disagreements I've seen in the breathing world is the emphasis between techniques vs habits. Those on the techniques side (such as anxiety specialists and Buteyko practitioners) present various techniques you can use when you are stressed, anxious, or have breathing difficulty. Those on the habits side (such as Peter Litchfield) say that techniques are mere bandage covering up a dysfunctional breathing habit, and that the solution is to unlearn the old habits and introduce new habits.

(actually i think *some* buteyko people have basically the same views as me.)

I find myself somewhere in between these two views. In a sense, I think both sides are right, and it's actually quite important to understand what's going on here. Techniques are a way of *learning* a thing. Once you've learned it, you don't need to "follow a technique" anymore, it's just a part of you. But having it verbally, explicitly, legibly, outlined is a useful step in actually learning the thing initially. You follow the technique, you get anxious about whether you're doing it right, you get obsessed about it, you get good at it, and then finally you get bored of it. It's all part of the *overlearning* process. Once your bodymind digests it, it poops out the scaffolding of the technique and

you can just Do The Thing. See also the four stages of competence (Wikipedia contributors 2023).

So yes, do the techniques. Learn them so well that you get bored of them and forget about them. Find the technique that you can do all day long, such that the technique *is* the habit.

10 Capnometry biofeedback

[TODO: fill out this section. It should be about how to use the capnometer well. maybe include my list of “things to try on the capnometer”. talk about what the ideal breathing curve should look like.]

Given how expensive capnometers are (and potentially difficult to access as well, if you don’t happen to have anyone near you who can rent them out), you might think they are not worth it. I think it’s fine to be skeptical of them. I personally made *some* substantial progress without a capnometer, but then 1–2 months after switching to nasal breathing I hit a plateau where I was still having significant shortness of breath while talking (and okay levels of shortness of breath while just sitting quietly). It was only after getting access to a capnometer that I had a second big shift in my breathing. See the section The unreasonable effectiveness of capnometers for more about why I think they are useful. But also, definitely try fixing your breathing without a capnometer first, and just see how far you can get! (reminder that i don’t sell or rent out capnometers, so i don’t benefit either way from your decision.)

the other important thing about capnometers: taking Control Pauses is frankly scary to me, and *some* people also seem to get unpleasant side effects when they do it (even when they’re doing it correctly – artour rakhimov talks the most about this, of the people i’ve read). so a capnometer is a way to measure progress in a completely safe way. (update (2024-02-25): i think i’ve warmed up to taking CP measurements a bit more now. the key is that if you’re doing it correctly, then you let go of your nose on the moment of the first inkling that you need a breath, way way way before any discomfort. people have a tendency to hold on too long, as a way of impressing themselves or others, because they want to feel like they are healthy. if your CP is half a second, then so be it. the important thing is that over time, no matter how small your initial measurements are, they will improve. i do still think some people get weird negative symptoms even if they correctly implement the CP, and this probably includes me, so even though i’m warming up to the idea a bit

more, i am not planning to start *daily* measurements of my CP, although i will probably check it once every few weeks maybe, just to see if it's still causing problems.)

TODO: what the heck do you do when your baseline CO₂ is normal according to the capnometer, but you still have that slight air hunger at all times (like, it's subtle enough that i wouldn't have even logged it in my symptom tracker before), and it's been over a week since you've been in this state (so bicarbonate levels should have adjusted by now)? that's the place i am in now (2024-01-29), and i'm not quite sure where to go from here. maybe trying to have this same breathing as i'm doing light exercise? or practice maintaining good breathing while i'm talking (my CO₂ goes down and i feel more out of breath when i talk, although it's gotten better as my baseline CO₂ has gone up)? or do i need to go into more advanced buteyko exercises like reduced breathing and breath holds? there was that thing in Chaitow, Bradley, and Chris Gilbert (2014, p. 6) Box 1.1 which says "General levels of deconditioning (the opposite of aerobic fitness) lead to altered forms of energy production (anaerobic glycolysis) that encourages acidosis – hence a greater tendency to hyperventilation" so it's possible i am also just deconditioned, and if i can just exercise more each day, everything will sort itself out. (as i write this i've only been going on walks of like 10–35 minutes in length and some stretches throughout the day. i used to run more but that routine keeps getting disrupted.)

10.1 The unreasonable effectiveness of capnometers

One might naively expect that capnometers would be useless, since they don't actually *do* anything to your breathing. All of the breathing changes you make are ones you make yourself, and the capnometer just tells you what your CO₂ levels are without affecting them. One might thus conclude that capnometers are useless. I don't have a great reply to this – in fact, some people seem to get better just by doing Buteyko breathing "blind" (i.e., without seeing their breathing curve using a capnometer). So clearly it *is* possible to do the same things without a capnometer. (Even Peter Litchfield admits this to some extent.³) But in my case, it was only after I got a capnometer that I saw rapid

³From Litchfield and Reamer (2024):

You may be wondering, "can I benefit from the course without using technology?" The answer, of course, is a resounding YES. The ultimate objective of breathing behavior analysis work is NOT about learning to use technology for

progress. Here I will try to build a model of *why* having a capnometer is so useful.

My model of why capnometers are so “unreasonably effective” is basically that with Buteyko breathing, part of the problem is that even if you make progress, you can never know if you’re pushing so hard that you’ve overshot your CO₂ and are now having too much CO₂. You can’t really avoid this problem because both too low CO₂ and too high CO₂ feel pretty much exactly the same – air hunger. So a capnometer is what actually lets you know for sure whether you are undershooting, just right, or overshooting.

It’s just super helpful to *see* what your breath looks like. Buteyko breathing can feel *scary* because you don’t know if you’re going too hard and might be harming yourself. Hooking yourself up to a capnometer tells you whether your CO₂ levels are normal.

one of the things i’m still trying to figure out is, supposedly Konstantin Buteyko originally had various machines to measure CO₂ or whatever, but then they were destroyed, so then he was forced to come up with the Control Pause as the sort of replacement metric (update(2024-02-10): actually, after reading the “destruction of the laboratory” book, i think this isn’t quite right. buteyko already had CP as a tool when he still had access to the combine-complexator, which is why he could make charts showing how certain pCO₂ levels correspond to certain CP lengths). but what i’m wondering is, what did his machines measure? was it just end-tidal CO₂? and if so, then what did he do after people reached a normal 40 mmHg of pCO₂? was that the end of treatment? or did he try to push the CO₂ even higher? Update(2024-02-10): See Altukhov (2009). for some reason, the CO₂ measurements are super high, and so apparently he just kept going until people reached the high CPs and high CO₂s.

all of the above being said, one of my goals with this document is to be able to write down instructions that are so precise that i could hand it to my past self who has no access to a capnometer and still completely cure air hunger. there will be a lot more guesswork/“feeling around blind” going on, but if the instructions are good enough then they should still work.

manipulating breathing with physical techniques, i.e., an outside-in paradigm, but rather it is about learning new breathing habits that automatically optimize respiration, that is, aligning breathing with respiration based on the principles of self-regulation, an inside-out paradigm. The CapnoTrainer GO technology is a powerful tool for making this transition from an outside-in to an inside-out paradigm, that is, for identifying existing habits and learning new ones.

10.2 Buteyko community

TODO: talk about buteyko's combine-complexator and my learned helplessness idea.

11 Breathing exercises

Reminder that none of these exercises will work if you can't breathe through your nose comfortably. See the section Clearing your nose for how to unblock your nose.

one of the things i've personally found frustrating is when people say "just do buteyko" or they link to a video with super vague instructions. so, at the risk of overfitting to my own experience, i'm going to give pretty precise instructions for exercises and aspirationally try to make them be difficult to misinterpret.

it's probably overwhelming to see all these exercises and giant walls of text. one of the nice things about working with a breathing coach is that they will guide you by only introducing one technique/exercise each week or so, so that at any given moment, you have *one* new thing to work with that you are trying to integrate into your practice. so a challenge for me is: if the reader isn't going to be working with a coach (which is presumably why they are interested in this document), then how can i make the exercise sequence friendly to them? i really need some sort of timeline or flowchart that can be followed, so that as little thought as possible needs to go into making decisions. it's all laid out, you just follow a recipe.

unfortunately the theory given in the section The biological basis of shortness of breath only says *that* you should breathe less to build back the CO₂ levels over time, but not *how*. The exercises given here are much more an art than a science. I'm most just writing from personal experience about what worked best for me. The only way you will know for sure if you are raising your CO₂ levels is to get a capnometer and measure your own levels.

11.1 Main practice: relaxed silent nasal breathing

This one is most similar to Rakhimov (2013, section 4.6, "Relaxing the diaphragm (Buteyko relaxed breathing exercise)"), but Neil Tranter also has a similar video (Tranter 2023). Andrey Novozhilov (2012) has similar exercises too (e.g., Exercise 1).

Exercise instructions: sit upright in a comfortable way. Breathe silently through your nose. Then just try to make sure the exhale is done in a completely relaxed way, where your whole body (but esp diaphragm) relaxes. You are *not* pushing the air out. Just a whole-body relaxation on every exhale. On each exhale scan *one* body part for tenseness: shoulders? torso? legs? etc. Just focus on one body part at a time, and try to relax it on the exhale, and keep it relaxed. The idea of this exercise is that just by relaxing the exhale, your breathing should slow down (but don't try to artificially slow down your breathing) and so it actually is a (mild) reduced breathing exercise even though it just seems like a relaxation one. Do this for 15 minutes or so. As you're doing this exercise, you don't want to be forcefully inhaling, trying to take in "good" breaths – your inhales are silent, after all. (If your air hunger gets so extreme that you feel like you're suffocating, then of course it's okay to take a forceful emergency rescue breath, but this also means your silent breathing was too shallow, possibly artificially restricted, or maybe you are not ready for this exercise yet and need to do one of the intermediate/temporary exercises.)

Attention drifting during the exercise is a *good* thing because you want to make sure this style of breathing becomes a *habit* (rather than only occurring when you are consciously executing the instructions). You want your mind to drift away from your breath, as a way of giving yourself small opportunities to see if you can maintain the same breathing pattern even when you are not paying attention. The important point is that whenever you realize you have drifted and you're aware of your breathing again, you want to gently check to make sure you're still doing the completely relaxed exhale, and that your body isn't tense. You can even try to intentionally pay attention to something else, to distract yourself, so that you can check back on your breath to see what it has been doing.

The whole exercise is basically juggling your attention in this way: Is my inhale silent or as quiet as I can manage without tensing up? Is my exhale completely relaxed? Are all of my body parts relaxed (except spine, to keep an upright posture)?

If you have trouble relaxing your exhale or knowing whether you are relaxing your exhale, try the [Double inhale technique] or try artificially slowing down just the first part of your exhale. These two techniques should give you an easier time relaxing the exhale so you will know what relaxation feels like.

Your hands may warm up a bit, and this seems like evidence that the exercise is working.

note that i use the word "silent" rather than "quiet" because for a long time

i thought my breathing was quiet, but it turned out my breathing was still making quite a bit of noise compared to what i *could* do. i don't want others to make the same mistake i did. if your hearing is normal, you should not be able to hear your breathing. if you are hard of hearing, then maybe get someone else to check for you.

the goal is to eventually be breathing in this way all the time. so it's a "technique" but also it is going to become a habit.

It's okay to have mild air hunger throughout the exercise. But you don't want too much. While your CO₂ tolerance is still very low, you might only be able to do the exercise for a short time, or you might need to do things like artificially lengthening the inhale.

an open question for me currently is: after you do this conscious relaxed silent breathing, you will build up some mild air hunger. now, *after* you complete the exercise, how long should you "keep" that air hunger going? should you feel free to just take a slightly deeper breath and "clear" the air hunger, or should you keep it going for some time (if so, how long?), or should you just try to keep it going as long as possible? i think trying to keep up the silent breathing with slight air hunger for long enough periods tends to cause a sudden burst of anxiety for me, like a sense of panic at not being able to breathe. so i think that's probably not the right thing to do. but it's confusing because i go from feeling totally comfortable with the slight air hunger to suddenly feeling panicky. Lippmann (2015) says "This process [raising CO₂ tolerance over time] is long and finicky and can cause very unpleasant symptoms. Less is more; barely knowing whether you're doing anything is best. You can also trigger panic attacks or asthma attacks if you're susceptible." Another thought is to, whenever possible when taking deeper breaths, to do so in more Buteyko-aligned ways, e.g., through the nose and as gently as possible. So don't satisfy the urge for a deeper breath by inhaling with your mouth or yawning or being super forceful about it, just try to gently incline towards a deeper breath, a slight force with your nose. NOTE: this may not be possible at first, e.g., i had to get to silent nasal breathing in order to take "good" breaths with little force through my nose. when i was still mouth breathing some of the time, i always had to take a good breath through my mouth. then when i started nose breathing (but loudly), i could take good breaths occasionally through my nose, but only by loudly sniffing in. so there's a gradual "handoff" where the old normal becomes the new "rescue breath" method.

Try slouching too as you do this exercise, and in general experiment with your posture. Your diaphragm will give you feedback on which postures work

best. For example, when I slouch as I do this exercise, I notice my diaphragm can't move as well (both for inhale and exhale). Being too upright also makes it seem like my whole torso is too "stiff". So some intermediate posture seems to work best for me, but idk yet if this is optimal.

I think this exercise might be "breathing-complete" in the sense that it's the only thing you need to cure shortness of breath – but I am still actively testing out this hypothesis. i also suspect this exercise is "universal" in the sense that it is particularly easy to stumble onto. i sort of (with a bit of help) stumbled onto it while using the capnometer. the buteyko people also recommend this (or slight variant) exercise for beginners.

relaxing completely is harder than it seems. I have a tendency to "relax" by like forcing my body to collapse, and that is not actually relaxation – on the capnometer i can actually see i am failing, because my CO₂ will go from like 38 to 34. you should not feel any strain or "tug" at all in your abdomen. i don't know how to convey the actual precise instructions necessary to do this; i personally am just getting feedback from the capnometer. when the capnometer tells me my CO₂ just went down from the new thing i tried, i'm like "ok, i guess that's not the right way to do it", and go back to my baseline breathing style, and then try another thing.

for me, even on 2024-01-29, doing this exercise for 10 mins caused a mild suffocation-like reaction after about 5 mins, where i freaked out and stood up and had to take a few (unsuccessful/unsatisfying) mouth breaths, and then had to like just let my body do whatever for a few breaths, and then try to get in some good nasal breaths. after that, i was able to return to the exercise again, but i had to keep indulging good breaths. idk, this exercise is a lot harder than it seems! it's weird though because i *feel* like i'm just doing this throughout the day, but i never get this suffocation reaction. so i wonder if it's just that i'm indulging good breaths throughout the day, but during this exercise i don't, and that's the crucial difference? i think i should start lower, like do this for 2 mins without indulging, then next day go up to 3 mins, etc?

Litchfield and Reamer (2023, p. 57) has an interesting prompt, "Do you feel air hunger before the end of the exhale?" It made me pause because I always thought I continuously have air hunger, but actually, paying attention, I don't have it on the inhale, even if it's soft. Then as the exhale progresses it slowly mounts, in a subtle way. I've noticed that paying precise attention to when the air hunger comes one actually diminishes the air hunger.

eventually, i think the goal is to do this exercise while walking, then while jogging, biking, etc.

another point: you don't want to just move your diaphragm. natural breathing actually involves movement of the whole torso, from upper chest to ribs to back to diaphragm. if you find that you are only moving your diaphragm, then this is a sign that one or both of two things are happening: (1) you're exaggerating the movement of the diaphragm; and/or (2) you're artificially suppressing movement of the rest of your body, tightening it up.

it might be helpful to do this exercise with a naked upper body and staring at a mirror, so that you can see exactly which parts of your torso are moving in what ways (you can also try it in the shower but your neck will be bent if you want to look down at your torso). alternatively you could put your hands on various parts of your chest and feel the movement.

any reduction in breathing *must* come from relaxation, *not* from tension/control. this is a good video <https://inv.tux.pizza/watch?v=uvWSwxKUK1A> (that i totally did not appreciate in the beginning, because i wasn't even trying to do any reduced breathing. but what i've realized is that relaxation=reduced, at least if your breathing is awful like mine. and sometimes you consciously or unconsciously try to make your breathing more silent, and you really don't want to do that by tensing up.)

11.2 Introductory exercise: Many small breath holds

Tranter (2022) – the actual exercise starts around 7:46. also note that he counts kind of fast. i think his “5 second” count is actually more like 3.5–4 seconds (i should verify). 5 seconds is actually quite a long time to hold your breath, if you have air hunger! don't be discouraged if you can't do an actual 5 seconds. even tranter's count down is enough to get you used to the idea that deliberately holding your breath a bit isn't going to kill you.

i think the main value of this exercise is at the start, to get used to very small amounts of air hunger, to be like “ok, yeah, this is uncomfortable but it won't kill me”.

you can try doing this both when you're feeling mostly ok and when you're having more trouble breathing. for me it was very easy when i was feeling ok, but quite challenging when i was having trouble breathing (so much so that i'd have to take “rescue” mouth breaths every few breath holds). you don't want to follow the video so literally that you feel like you're suffocating; the idea again, is to just get used to doing breath holds and intentionally building up mild air hunger. so this is more of a *psychological* exercise than a physiological exercise.

i currently don't recommend doing longer breath holds. i think it helps for some people, but i think there is more risk, and i am pretty sure it's not required for fixing air hunger.

11.3 Intermittent technique: Double inhale technique

you take two relatively quick inhales, then exhale in a relaxed way.

This one was shown to me by my breathing coach. I've found this quite useful for getting my body to relax the exhale. i have no idea why it works, but somehow it's just easier to exhale in a relaxed way from a more full inhale.

11.4 Intermittent technique: Slowing the first part of the exhale

TODO: fill out. this one is similar in intent to the previous technique.

11.5 Intermittent technique: watching automatic breaths

Usually I have found that if I start paying attention to my breaths, my breaths become consciously controlled ones, i.e., non-automatic. This brings up a question of whether it is possible to "study" your own automatic breaths without controlling them (e.g., to find what your natural breathing rhythm is, or because your automatic breaths are better).

One natural idea is to just record yourself all the time, or to have someone watch you all the time, so that they can catch you when you're not focused on your breaths. But this requires a lot of setup and I am not even sure that your breaths will be the same when hooked up to a machine.

If you feel like even when you are trying to just let the breath naturally happen (when doing the main exercise) that you are somehow controlling or manipulating your breath (which expresses itself as discomfort/air hunger, pain in your diaphragm, a feeling that your throat is subtly being choked, etc.), then this exercise might help.

Exercise instructions: lightly tap your teeth kind of as if you are chattering from being cold. You can tap along to some song you like. What I've noticed is that since I have to tap along to the song, I can't control my breath as well, *but* I can still "watch" the breaths without controlling them. If you have more

musical talent or experience then it may require a more complex pattern to distract you away enough from controlling your breath.

By tapping in a simple rhythm lightly with my teeth, like
. . . or something repeatedly, if I focus on the tapping, then my breathing becomes automatic. But because the teeth are close enough to the nose, you can kind of “watch” your nose automatically breathing.

One tricky thing is that when I tried this while walking, I found myself wanting to breathe at the same rhythm I was tapping with my teeth, which is not what we want.

I have found better luck when lying down on my back and just tapping with my teeth lightly, and watching my breaths.

11.6 Temporary exercise: soft smooth slow long inhales

TODO: explain this exercise. it’s transitory because eventually (within like a week or two) you want to switch to the relaxed silent breathing. this exercise is a crutch for when relaxed silent breathing is too hard.

11.7 Temporary exercise: soft long exhales

this is the counterpart to the previous exercise.

i think the idea with these two exercises is that you’re focused on just *one* half of the breath, and trying to do that half correctly. but the other half you can just do whatever. eventually, you will be able to just do the main exercise (i.e., both halves). in fact, you should eventually notice that slowing one half of the breath (esp inhale?) will lead to slowing the other half too.

once you start doing the main exercise, these transitory ones will feel extremely unnatural.

11.8 Intermittent technique: distraction

when you feel out of breath (e.g., after talking) and just sitting there quietly isn’t helping, this is a sign that you’re still somehow, on some level, interfering with your breath and trying to control it. one way out of this, at least as a temporary measure,⁴ is to just totally distract yourself in some way so that

⁴Hopefully at some point I will figure out a better way out of such situations. I’ve found that like 80% of the time just sitting quietly and with decent posture and breathing silently

you're not paying attention to your breathing at all. this will tend to "reset" your unconscious breathing pattern, back into a "good" state. you can try any of the following, or even anything else that you can think of:

- pace around the room (note: you probably don't want to go on a *walk*, which might make you exert too much and then you might feel a bit out of breath for a different reason, at least, if you happen to be deconditioned like I am)
- go make some tea
- go prepare some food to eat
- go pee
- read something
- watch something, like a youtube video or movie
- play a video game
- pet an animal (assuming you don't have allergies)
- take a nap
- brushing your teeth/flossing (personally I tend to notice my breathing is better after I brush my teeth and floss at night)

you can even combine any of the above, like pacing around *while* listening to a podcast.

you probably don't want to do something that requires a lot of mental exertion (like reading a difficult book) or that induces stress (like watching a thriller film). you want something that is distracting enough that you're not thinking about your breath, but also something that is "ordinary" enough that you're not unconsciously manipulating your breath in weird ways. a mild distraction, not an engrossing activity.

also possibly just for me, but eating/drinking is kind of stressful because i don't know how to coordinate the moments when i need to hold my breath when i swallow. so for me, eating food would not be a good distraction.

through the nose will dissolve the air hunger feeling to a small enough level that I don't even think about it. So this distraction technique is helpful in the remaining 20% of times. But I'm hoping that I can figure out some better, less artificial, solution for what to do in those 20% of times.

12 Posture

I'm appreciating posture more now – it really makes silent relaxed breathing easier when you have better posture. But “good posture” is maybe not what society thinks is good posture, but whatever feels comfortable to you and allows for good breathing.

The Buteyko people also emphasize posture, but I have not read much about what they say. what i've seen is basically “sit at the edge of a hard surface with back straight”.

i still have a lot to learn here. apparently some posture techniques can be quite dangerous (can even cause die-off reactions??)

what can sometimes *feel* like air hunger might just be your abdomen being compressed due to slouching. sitting up a bit straighter can reduce the air hunger feeling. (this doesn't work most of the time)

i think posture matters more the lighter your breathing becomes. during reduced breathing exercises i think it's especially important. i notice if i'm slouched my breathing is more forceful. the problem is that i get back pain if i am sitting upright for too long (in supposedly “good” posture). so i need to figure what's optimal in the long run. there's got to be a way to get both good breathing and good posture and no back pain; i just don't know how yet.

i've been kind of going through a loop of {feeling tired -> slouch -> feeling like i can't breathe as well -> sit up straight}. and then also sitting in different ways (cross-legged, seiza, normal, against back rest, not against back rest, which gives you like 6 combinations, and if you add slouch/straight then that's 12 configurations on the chair). and i think this is probably good, to just be changing posture and sitting style all the time, like every few minutes.

13 Breathing synthesis

My synthesis = “Buteyko method” + “Alexander Technique” + Capnometry biofeedback

or maybe:

My synthesis = Nasal breathing + Silent relaxed breathing + Posture + Habits + Capnometry biofeedback

- Buteyko provides nasal breathing, silent breathing and a theory of air hunger via CO₂ levels. I put it in quotes because this is probably a vast

oversimplification of the Buteyko method – but I only needed this much of the theory.

- “Alexander Technique” is what I mean by just allowing the breath to happen: smooth, not jerky. “Allowing the breath to happen” rather than doing the breath. And also making the good breathing a *habit* rather than “executing techniques” when you need them. Make it automatic/autonomic/subconscious/unconscious, rather than conscious/manual – this one might be two separate things actually (the smooth part, and the unconscious/habit part). Some of the Buteyko people also *mention* this, but it tends to be much more buried and not *emphasized*. I think it really needs to be thought of as one of the main components.
- Capnometry biofeedback is discussed elsewhere in this document, e.g., see the section The unreasonable effectiveness of capnometers. In some sense this one is *also* part of the Buteyko method, except that the Buteyko community moved away from capnometry after their equipment was destroyed/confiscated. So in some sense I am picking and choosing the specific parts of Buteyko that I like, so it’s turning out to be less a synthesis and more a distillation.

14 Misconceptions

this section is mostly an index to stuff discussed elsewhere in the document.
(might remove this section if it doesn’t seem useful)

- CO₂ is bad – see Misconceptions about CO₂
- deep breaths are good
- diaphragmatic breathing is good
- you want to slow down your breath/breathe to a certain rhythm

Acknowledgments

i’ve benefited from interacting with a lot of people, in the course of figuring out my breathing. (people who i haven’t checked with to see if they want to be mentioned are listed as initials, unless i’m only relying on public sources and no private interactions, which applies to Howard Cooper.) Being acknowledged does not mean that the person agrees with anything I wrote in the document.

- ML: kept mentioning buteyko breathing to me saying i should try it.
- Howard Cooper: While I've benefitted from all the sources I'm citing in the References, I want to call out especially Cooper (2021) as the thing that finally made the CO₂ stuff click for me (though my understanding was still very incomplete) and got me to actually start playing around with buteyko techniques.
- CM: told me about the capnotrainer and got me excited about capnometry biofeedback.
- Vipul Naik helped me understand some key things about the biology of respiration. In particular, he was the one who figured out that having a low CO₂ means pH is more sensitive to slight fluctuations in CO₂ levels. also for reading drafts of this document and giving me feedback. most of the things in this document i wrote up while discussing it with vipul.
- DD: introduced me to JA. he was also a catalyst for me figuring out my circadian rhythm, but that's a whole separate topic.
- JA: my breathing coach; helped me get set up on the capnotrainer, and helped me through the whole biofeedback process.
- PL: was generous enough to spend an hour talking to me about capnometer stuff.

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