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# Breath is life yogic breathing is highest protection to life

## Abstract

Yogic breathing enhances health and aids healing. Some important yogic breathing pranayama exercises are described with their benefits and limitations. Yogic breathing helps to purify the blood, clear the nasal passages and sinuses, improve blood circulation, tone the nervous system, and generate pranic vitality. It controls the acid-alkaline balance of the immune system, reduces the risk for the formation of kidney stones, helps to reduce the body weight. Pranayama reduces stress and anxiety, calms the mind, and removes depressive disorders. Further pranayama exercises reverse diabetes, protects against cancer, detoxifies the body, lowers the cholesterol levels, and improves blood vessel function. During yogic breathing exercises, the vital capacity of the lungs goes up to 3800ml which is almost 7-8 times higher than during normal breathing. ROS in the body generates. OH, radicals which being extremely reactive instantly attack the glucose molecules at its terminal groups to form several useful products including D-glucaric acid. Ca-D-glucarate has been shown to decrease lung, skin, liver, breast and colon cancers by 60% or more.[1] The other products of oxidation of D-glucose in the residual portions were identified as D-gluconic acid, D-glucuronic acid, and D-glucono 1,4 lactone. Aqueous solutions of D-gluconic acid contained glucono delta lactone which exhibit strong chelating activity towards calcium, iron, aluminium, copper, and other heavy metals and removes some undesirable and unwanted metals from the body. Glucuronic acid has some strong detoxifying properties. Its main function in the body is to combine with drugs, toxins, and hormones, and either to carry them to different parts of the body or eliminate them.

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## A. Breath and yogic breathing

### A-1 Breath is Life

*"To breathe means to live and to live means to breathe. life is not possible without breathing.*

*The cessation of breathing is cessation of life".*

Swami Vishnu Devananda[2]

Life is impossible without air. We can survive without food and water for some time, but if our air supply is stopped we will be dead in a few moments. Oxygen is required to burn waste materials from our body so as to purify the blood stream. In the modern world, we have lost the art of breathing properly. The shallow breathing utilizes only about 1/10 of the lung capacity, [3] lack of oxygen causes headaches, fatigue, and lack of mental alertness. Yogic breathing exercises if done accurately and without any strain can lead to greater bodily vitality, calming the mind and emotions.[2]

According to Cynthia Worby[4]

*"The breath is the vehicle for prana, the vital energy force. It is the universal energy that sustains all life. The prana enters the body upon inhalation, supplying every cell with energy, oxygen and nutrients. The breath is the bridge between the physical and spiritual worlds".*

### A-2 Sources of prana

We obtain prana from rest, food, water, sleep, sunshine, and being in a peaceful and quiet state of mind. There is more prana in fresh foods than in canned or stale foods. Vegetarian food has higher prana values than flesh food, which is supposed to be made of dead animals. Meat has a lower or negative value for prana. The most direct and immediate source of prana is breath. The way we breathe has a powerful effect on how we feel.[5]

Pranayama is done to redistribute prana, the vital energy force throughout the body. If certain parts of the body lack in prana, it will become unhealthy and result in diseases. The reduction in life force (prana) by improper breathing results in the shortening of the lifespan. In classical yoga books, breath is mentioned as a "string which controls the kite".[6] The mind is considered as a kite and the breath as string. As the breath moves, so moves the mind. If our breathing is short and rapid, our mind will work nervously and agitatedly. If breathing is erratic, our mind will be disturbed and anxious.

If our breathing is long, slow and smooth, our mind will become quiet and peaceful. The breath is a link between body and mind.

### A-3 Some important quotations on breathing as given by some yoga masters

i. *"Breathing is physical part of thinking and thinking is the psychological part of breathing"*

Ayurveda – Benefits of Breathing Exercise: Pranayama - Conscious Health

ii. When the breath wanders, i.e., irregular, the mind is also unsteady, but when the breath is still, so is the mind.

Hathayoga Pradipika – https://consciousheath.net/pranayam-breathing-exercise-conscious-health-nahid-ameen/

iii. *"A man is said to live only so long as he is breathing; when the breathing cease, he is said to be dead".*

Hatha Yoga Pradipka/Swami Vishnudevananda

iv. *"When nadis are full of impurities, the breath does not go to middle nadi, sushumna – then there is no arriving at the higher state of mind"*

Hatha Yoga Pradipka/Swami Vishnu…

v. *"Yoga links the breath to the body. The breath is the bridge between mind and matter, between body and spirit. During inhalation, we are receiving life. Upon exhaling, we are returning what we do not need and ridding the body-mind of impurities".*

Everything Yoga book - Cynthia Worby

vi. *"If we understand the rhythm of our breath, we are able to have a say over our mind, we can win over any negative emotions like anger, jealousy, greed, and we are able to smile more from our heart".*

Sri Sri Ravi Shankar/Art of Living

## A-4 Yogic breathing (pranayama) exercises

Yogic science of breathing is called pranayama. By controlling the act of breathing we can efficiently control all the various motions in the body and our nervous system. We can easily and quickly develop body, mind, and soul through breath control exercises. The breath, directed by thought under the control of will is vitalizing, regenerating force which can be used for self-development and healing several incurable diseases.[7] Some important Pranayama exercises are described below and their benefits are mentioned.

### A-4.1 Breathe Better

With the practice of Pranayama, the respiratory muscles and the lungs function more effectively. This leads to a greater betterment of psycho-physical well-being and increases bodily vitality, improves air processing in the lungs, purifies the blood, calms and tunes the nervous system, and fosters mental poise and equanimity. It gives relaxation to the body and mind and dissolves tension. Pranayama is done to distribute prana, the vital energy force, throughout the body. After the practice of asanas, the body is ready to get prana. There are three main stages in pranayama –

i. Inhalation (Puraka)

ii. Exhalation (Recaka) and

iii. Retention (kumbhka)

The lengths of inhalation, exhalation and retention are different in different types of pranayamas. Every cell in the body gets oxygen and nutrients and is nourished by the breathing exercises.

### A-4.2 Kapal bhati

In Sanskrit (ancient Indian language) Kapal means forehead and bhati means shine. Therefore, practicing kapal bhati on a regular basis leads to a shining face with inner lust and glow. Kapal bhati is a highly energizing abdominal breathing exercise. This process cleans the skull and therefore is called one of the shat-karmas or six cleansing processes as mentioned in Hatha Yoga. It cleanses the respiratory system and the nasal passages. It removes the spasm of the bronchial tubes. Consequently, asthma is relieved and cured in the course of time.[7] Lungs are fully oxygenated and are considerably developed. Carbon dioxide is eliminated in large quantities. Impurities of the blood are thrown out. Tissues and cells absorb large quantities of oxygen. Thus, Kapal bhati removes waste materials which our organs are not able to throw off. In some cases, yogic breathing even assists the nature in removing waste products and the practitioner keeps up good health.

### A-4.21 How to do kapal bhati pranayama

I. Sit in comfortable crossed leg position, keeping the spine straight and hands resting on the knees in Chin Mudra*, eyes closed and face relaxed.

II. The best place for Kapal bhati is a peaceful area with greenery around and oxygen in abundance.

III. Kapal bhati should be practiced in the early morning when the stomach is empty, or it can be done five hours after the meals.

IV. The process of doing Kapal bhati is very simple. This is a breathing exercise which helps to oxygenate our body while strengthening the muscles of the stomach and abdomen. It consists of short powerful exhales and passive inhales through both nostrils. Inhales are mild, slow, and longer than the exhales. In this process, we take a deep breath and exhale with all force and vigor so that the stomach will go deep inside.

***What is Chin Mudra?***

*Chin Mudra is a combination of two words, chit and mudra.[8] Chit means consciousness and mudra is a gesture. In this mudra, the tip of the thumb touches the tip of the index finger while other fingers are left free. The connection of the tip of these two fingers makes it Chin Mudra.* (Figure 2).

**Figure 1** Chin mudra.

*This mudra connects[9] us to our higher self, helps lift dull energy, creates a more receptive state, calms the mind and brightens the overall mood. It is often used in meditation, pranayama, and asanas.*

According to Rekesh Pradhan (Rakesh yoga).[10] "This mudra helps to cure insomnia, increases energy and stamina power. Regular practice of this mudra can eliminate all psychological disorders like anger, depression, stress, and anxiety. Improves sleep patterns and reduce all lower pain".

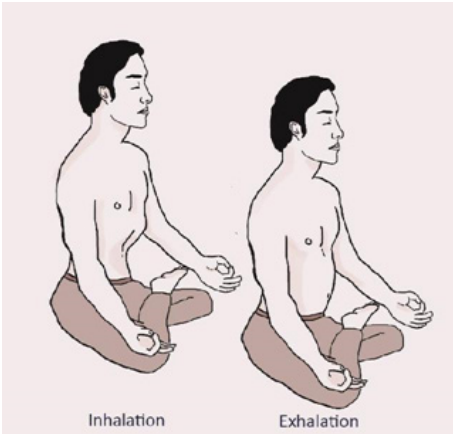


**Figure 2** Kapal Bhati Pranayama.

Some traditions [11] give duration of inhalation and exhalation as equal, but others suggest that out breathing should take only half the time as taken by in breathing.[12]

Each passive inhalation should take one second and exhalation should take same or half the time. In the beginning [13] a round should

have 15-20 expulsions. New practitioners are advised to practice three rounds of 15 expulsions each before practicing pranayama which can be done twice a day, 5 hours after meals. If done under the guidance of a qualified yoga teacher, 10 expulsions can be added every week until one reaches 120 expulsions in each round. Between rounds, take few normal respirations while resting. The number of expulsions can be increased further with the advice of a teacher, but under no circumstance should one go beyond his capacity. Overdoing should be avoided.[4]

V. While doing this exercise, think that while exhaling you are throwing out all of the diseases from your body. Practitioners with abnormalities such as anger, greed, and ego should develop a feeling of throwing out all the negative injurious elements along with the air exhaled.[14]

VI. After the number of rounds, relax and breathe normally until breathing rate comes back to normal. The relaxation period can be roughly between 30 seconds to a minute.[12]

**A-4.22 Cautions and side effects of kapal bhati**

1. **Avoiding hyperventilation***: If Kapal bhati is done for the first time, one may feel dizziness which is caused by hyperventilation as mentioned by Swami Vishnudevananda and coworkers.[15] It was further suggested that if this happens, stop kapal bhati immediately and lie on your back to relax. Once dizziness has gone, check if one of the following mistakes were made –

(i) Check that only the abdomen moves during both exhalations and inhalation.

(ii) Check that your abdomen is actively contracting and moving inwards every time you exhale.

(iii) Inhale passively so that the abdomen simply moves forward into a neutral position.

(iv) Reduce the speed of the pumping for two seconds for one set of inhalation and exhalation.

(v) In case of cardiac problems, high blood pressure, stroke, gastric problems, ulcers, etc., slow pace of Kapal bhati is recommended. The time of exhalation should be one second or slightly more.

(vi) Kapal bhati should not be practiced if an asthmatic attack is in progress.

(vii) Ladies during pregnancy or menstruation periods should not do Kapal bhati.[15]

**A-4.23 Benefits of kapal bhati**

Although Kapal bhati is one of the cleansing processes (shatkarmas), it can be considered as a vigorous breathing exercise which cleans the abdominal organs, lungs, nasal passages, and strengthens the heart and nervous system. It purifies the frontal region of the brain. It cures asthma, diabetes, digestive disorders, and is used as a technique for losing weight. Kapal bhati is a good way to release anger, stress, or any mental discomfort.[5]

*Hyperventilation is a condition in which we start to breathe very fast.[16] Healthy breathing occurs with a healthy balance between breathing in oxygen and breathing out carbon dioxide. This balance is upset when we hyperventilate by exhaling more than we inhale. This causes a rapid reduction of carbon dioxide in the body. Low carbon dioxide levels lead to narrowing of the blood vessels that supply blood to the brain.

This reduction in blood supply to the brain leads to symptoms such as lightheadedness and tingling in the fingers. Severe hyperventilation can lead to loss of consciousness.[16]

**A-4.31 Bhastrika**

Bhastrika Pranayam is also known as bellows breathing. In fact, in this pranayam, the lungs and abdominal muscles function like belows. Both the inhalation and exhalation are forceful. Bhastrika pranayama is the process of rapid inhalation and exhalation which gives a boost to the body and is therefore called as the yogic breath of fire.[17]

**A-4.32 How to do bhastrika pranayama**

Sit in sukhasana or any other meditative posture. Keep the body above the waist straight and the spine erect. Eyes can be kept closed.[18]

Take a deep breath and fill your lungs fully with air and then breathe out forcefully through the right nostril. Start with 3 rounds of ten pumpings and work up slowly to a hundred pumpings and a maximum of eight rounds.[19] Inhalations and exhalations should be deep and thorough using the diaphragmatic muscles. The exercise should be stopped immediately if discomfort is felt at any time. Some authors have suggested only 3 rounds of 20 breaths[17] with few normal breaths in between.

**A-4.33 Benefits of bhastrika pranayama**[20,21]

(i) This pranayama cleans the body and mind and improves blood circulation.

(ii) It removes toxins and impurities from the lungs.

(iii) Improves awareness and concentration of the mind.

(iv) Relieves stress and cures depression and hypertension.

(v) Calms the mind.

(vi) Cures asthma, headaches, migraines, etc.

**A-4.34 Limitations**

This pranayama should not be practiced by those[22] suffering from heart ailments, hypertension, and high blood pressure, intestinal disorders, spinal abnormalities, eye ailments such as detached retina or glaucoma, and during pregnancy period.

**A-4.41 Bahya Pranayama**

Bahya pranayama is one of the vital breathing exercises in which one breathes in forcefully (inhale), breathes out (exhale), and then holds their breath (retention).[23]

The meaning of Bahya is external or outer, and pranayama is a breathing technique. Therefore, the meaning of Bahya Pranayama is external retention. The ratio between inhalation, exhalation, and retention is 1:2:3, i.e. if one inhales for one second, then exhalation should be done in 2 seconds and outer retention should be 3 seconds. In case the period of inhalation is increased, the other two should also be increased in the same ratio.

**A-4.42 Sitting for Bahya Pranayama:**

(vii) Sit in padmasana or any other meditative pose.

(viii) Take deep breath and breathe out fully so as to evacuate the lungs to maximum.

(ix) Apply the following Bandhas[24,25] –

(x) Hold the breath and chin to the chest (Jalandhar Bandha or Throat Lock).

(xi) Pull the stomach in and up in the rib cage so that the stomach and back seem to touch each other (Udiana Bandha)

(xii) Lift the muscle from groin area (Mulabandha or root lock)

(xiii)Hold the three bandhas for 10-15 seconds

(xiv)Repeat[25] Bahya Pranayama for 2-5 minutes daily.

**A-4.43 What are Bandhas?**

*Bandhas control and lock the energy (Prana or life-force) in the body in the way we desire. Bandhas are used to control the energy system and transfer this energy to the parts of the body wherever it is required.*

*There are three major bandhas, Jalandhara, Uddiyana, and Moola Bandha that lock the energy in the throat, abdomen, and pelvis.*

*(i) Jalandhara Bandha*

*In this bandha, while retaining the breath, chin is firmly pressed into the chest. This prevents prana escaping from the upper body. For releasing this bandha, head is lifted while exhaling.[25]*

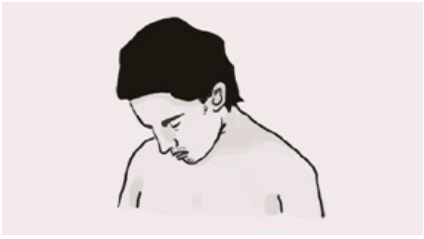

**Figure 3** Jalandhara Bandha

*(ii) Uddiyana Bandha*

*After exhaling completely, abdomen is pulled up and pushed back toward the spine. This forces prana up the sushumna nadi.[26]*

**Figure 4** Uddiyana Bandha

(iii) Moola Bandha

*Moola bandha literally means "Root lock". This bandha locks the energy in the pelvic region of the body. This lock includes the contraction of perineal muscles to lock the energy in the pelvic area.[27]*

**Figure 5** Moola Bandha.

**A-4.44 Benefits of bahya pranayama**

a) It is helpful in all abdominal problems[28] like constipation, acidity, gastricproblems, and hernia, etc.

b) It improves concentration of mind.

c) It improves digestion.

d) It cures problems related to reproductive organs.

**A-4.45 Precautions**

i. This pranayama should be done on an empty stomach or five hours after meals.

ii. Practitioners with heart or high blood pressure problems should avoid practicing this pranayama.

iii. Ladies during pregnancy or menstruation periods should not do this pranayama.

**A-4.51 Alternate nostril breathing (Anuloma viloma pranayama)**

In this pranayama, we breathe slowly, smoothly, and deeply through one nostril, the other being held closed, either with the thumb (right nostril) or the ring and middle fingers (left nostril) of the right hand (Figure 6). This pranayama purifies the nadis or nerve channels and soothes the nervous system. It is a very important pranayama exercise to soothe the nervous system and oxygenate the blood.

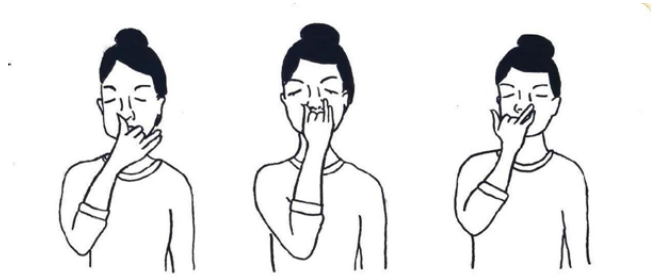

**Figure 6** Breathing through the right nostril Breath retention Breathing through the left nostril

**A-4.52 Sitting for anuloma viloma pranayama**

The following procedure as suggested by James Hewitt can be adopted

Sit in padmasana or any other meditative posture, keeping the head and back erect and right hand in front of the face in Vishnu Mudra.*

(i) Hold right hand up to the nose and close the right nostril with the thumb. Close the eyes.

(ii) Exhale steadily through the left nostril until the lungs are emptied.

(iii) Inhale slowly, smoothy, and deeply through the left nostril until the lungs are comfortably filled. Breathe in deeply by filling lower, middle, and upper lungs as much as possible.

(iv) Close the left nostril with the ring and little finger of the right hand. Both nostrils are now blocked. Hold the breath easily and steadily in the lungs for a few seconds. The chin lock may be applied (retention).

(v) Now open the right nostril by removing the thumb and by keeping the left nostril still blocked. Remove the chin lock by raising the chin from the chest.

(vi) Exhale slowly and smoothly through the right nostril until the lungs are emptied.

(vii)Pause for a second or two and inhale through the right nostril comfortably and keeping the left nostril blocked. Retain the air for a few seconds without any strain.

### *Vishnu mudra

In this mudra, we hold the right hand facing towards us. The index and middle fingers of this hand are folded over and pressed against the palm. The thumb, ring, and little fingers are kept straight (Figure 7).

**Figure 7** Vishnu mudra

(viii) Open the left nostril and exhale slowly, smoothly, and continuously through the left nostril until lungs are emptied.

This completes one round. The inhalation, retention, and exhalation ratio[11] should be 5:10:10, which can gradually be increased to 6:12:12 or 7:14:14. Practice up to 10 rounds.

#### A-4.53 Benefits of anuloma viloma pranayama

Deep and fine breathing is possible with the alternate nostril breath. The benefits are[29] that it aerates the lungs richly, cleans the nasal passages and sinuses, purifies the nadis (nerve channels), richly oxygenates and purifies the blood, tones and soothes the nervous system, stimulates the appetite, relaxes and refreshes the body, and calms and steadies the mind. According to Manish Sharma,[29] "*it increases mental stability, calms the mind, improves blood circulation and keeps away heart problems".*

#### A-4.54 Precautions

This Pranayama should be performed on an empty stomach or 4-5 hours after meals.

(i) Practitioners having high blood pressure, diabetes, or during pregnancy should avoid practicing this pranayama.

#### A-4.61 Ujjayi (Victorious breath)

Ujjayi is another important and useful variety of pranayama. Theos Bernard[30] calls Ujjayi as an easing method of chest and deep breathing. The chest is expanded in this pranayama for 'Jaya', which means victory, triumph, or conquest. The abdomen is kept slightly contracted and the thoracic cage is expanded fully.

#### A-4.62 Sitting for ujjayi pranayama

(i) Sit in any meditative posture, keeping the spine and head erect. The hands stay cupped in the lap and arms are straightened so that the back of the right wrist rests on the right knee and the back of the left wrist rests on the left knee in chinmudra (symbol of knowledge).[11,31]

(ii) Close the mouth and inhale slowly through both nostrils in a smooth and uniformmanner. During inhalation partially close the glottis in order to produce a sobbing sound of low, but sweet and uniform pitch. At the end of inhalation, perform moola bandha, and anal contraction and hold the breath with Jalandhara bandha by pressing the chin against the chest. The two bandhas are applied as long as we can hold the breath. Before exhalation, unlock the bandhas and keep the head and neck in a straight position. Air is exhaled through the left nostril with closing the right nostril with the thumb. Note that in Ujjayi, the inhalation is through both nostrils and exhalation is through only the left nostril.

(iii) This is one round of Ujjayi. To start with, 5 rounds can be practiced which cangradually be increased to 20 rounds in each sitting.

#### A-4.63 Benefits of ujjayi pranayama

Ujjayi Pranayama removes phlegm from the throat. The practitioner is never attacked by diseases such as nervousness, indigestion, dysentery, enlarged spleen, consumption and cough etc. Perform Ujjayi to destroy decay and death.[32]

#### A-4.71 Bhramari pranayama

Bhramari Pranayama is the action of making a humming sound while doing the pranayama. Bhramari is a Sanskrit word derived from Bhramar which means "humming black bee".[33] It is a calming breathing practice that soothes the nervous system and helps us to connect ourselves with truest inner nature.[5] Bhramari pranayama is very effective in instantly calming down our mind. It is one of the best breathing exercises to release the mind of agitation, frustration, or anxiety and to get rid of anger.[34]

#### A-4.72 Sitting for Bhramari Pranayama

(ix) Breathe in until your lungs are filled with air. Close your ears with both thumbs and eyes with middle fingers of your hand on both sides with little pressure. Press forehead with both index fingers lightly. Close both eyes, then press eyes and nose bridge from the sides of the remaining fingers. This is the procedure described by well-known yoga guru Swami Ramdev.[35]

**Figure 8** Bhramari Pranayam.

(x) Concentrate your mind on the Trikuti (space between eyebrows

(xi) Begin exhaling slowly with a humming sound of a bee and recite "Om" mentally. Repeat the exercise 11 to 21 times according to your capacity.

#### A-4.73 Benefits of bhramari pranayama

It has a positive effect on whole mind and body, particularly on the nervous system. Bhramari is practiced regularly during pregnancy. It facilitates easy and trouble free child birth. It reduces cerebral tensions, anger, anxiety, insomnia, and normalizes blood pressure.[35]

## B-Pranayama and body chemistry

### B-1 Pranayama and body chemistry

The term pranayama consists of two terms, prana and yama. One of the meanings of prana is "breath" and yama is "restraint" or

"control". Therefore, pranayama can be called as "breath control". The flow of breath in and out of the lungs is regulated and is made slow and smooth by pranayama exercises. The other meaning of yama is "tendency to retain strength". In yogic breathing, breath and vital cosmic force together are used to promote physiological, mental, and spiritual advantages of the body.

Many people have lost the technique of using their respiratory muscles and lungs properly and the result is destructive to health. The blood stream is not fully oxygenated and food is not adequately burned in the body to provide sufficient energy. This results in many health problems like headaches, fatigue, etc. In deep breathing, the shallow upper chest inhalation should be replaced by diaphragmatic and abdominal breathing which can be done by pranayama exercises.

## B-2 Need for oxygen

Oxygen is the utmost need of the human body. Our billions of body cells need to breathe. They need oxygen and return carbon dioxide, the waste product of metabolism. The atmospheric air contains 21% oxygen. The lungs pass oxygen from the inhaled air to the bloodstream which is carried to the cells. The cells then return carbon dioxide, which is expelled by the lungs on outgoing breaths. A large quantity of oxygen is needed for the combustion of food products (oxidation). The amount of oxygen we absorb through skin is not sufficient, therefore we depend on the efficient functioning of muscles and organs. Pranayama exercises play a great role in providing the needed oxygen. Through the practice of pranayama, the respiratory muscles and the lungs function more effectively. Yogic breathing increases bodily vitality, improves air processing in the lungs, purifies the blood, and calms and tones the nervous system.

## B-3 Consumption of oxygen during kapal bhati, bhastrika, and ujjayi pranayama

Dr. Kovoor T. Behanan[35] measured the consumption of oxygen in kapal bhati, bhastrika, and Ujjayi. He found that increased oxygen consumption over normal breathing for kapal bhati, bhastrika, and Ujjayi were 12%, 18.5%, and 24.5% respectively. It should be remembered[7] that kapal bhati and bhastrika are rapid cleansing breaths with a different role from Ujjayi. Kapal bhati cleanses the respiratory system and nasal passages. It removes the spasm in the bronchial tubes.[36] The apices of the lungs get proper oxygenation. Lungs are considerably developed. Carbon dioxide is eliminated in large scale. Impurities of the blood are thrown out. Tissues and cells absorb large quantities of oxygen. The practitioner keeps up good health. Heart functions properly. The circulatory and respiratory systems are toned to a considerable degree.

Chemically, kapal bhati is an oxidation process*. It oxidizes the waste material and toxins in the body to CO2, which is eliminated during the process.

The cell membrane and other structures such as cellular proteins, lipids, and DNA are damaged in the human body during the process of oxidation. An overload of free radicals in the body causes[37] several diseases such as heart disease, liver disease, and

**Oxidation is a process in which a loss of elections or an increase in oxidation number of a molecule, atom, or ion takes place. Similarly, reduction is a process in which electrons are gained or decreased in oxidation state of molecule, atom, or ion. These reactions in general are called as redox reactions.*

some cancers. The rate of this oxidation can generally be increased, by stress, cigarette smoking, alcohol, sunlight and pollution, etc.

## B-4 Free radicals

By definition, free radical is an atom, molecule, or ion that has unpaired valance electrons.[37] These unpaired electrons make free radicals highly chemically reactive towards other substances or even towards themselves, forming dimers or resulting in polymerization. A free radical is easily formed when covalent bond between two entities is broken and one electron remains with each newly formed atom.[38]

Free radicals in the body stabilize by "stealing" electrons from other substances, like nucleic acids, lipids, and carbohydrates, etc. These reactions are called as redox reactions. The molecule that picks up an electron is reduced, and the molecule that loses an electron is oxidized. The loss of an electron through the oxidation process generates free radicals. If the generation of free radicals is left uncontrolled, it takes the form of a chain reaction and it results in cellular damage and can cause several diseases.[39] It is well known that free radical damage occurs and this is probably connected with aging, heart disease, cancers, and some other diseases.

Although free radicals are very dangerous, they are still useful for the body in some ways. White cells in the body use free radicals to bond with invading bacteria and viruses and kill these invaders and save our lives.[40] It is said that oxygen is both a blessing and a curse. People need oxygen in order to live, yet the simple act of breathing in oxygen results in the formation of highly reactive molecular species called free radicals. As the free radicals interact with other molecules in the body, they can cause oxidative damage and result in a wide range of diseases.

## B-5 Reactive Oxygen Species (ROS)

Reactive oxygen species are formed during the reduction of oxygen to water Approximately 98% of the total inhaled oxygen by the body is used in the process of Lipolysis , the inflammatory process,[41] the production of chemicals [42] and several other biological processes. However, the remaining 2% of oxygen leads to the formation of three major reactive oxygen species (ROS). These are superoxide, hydrogen peroxide, and hydroxyl free radicals. Their electronic structures are given below (Figure 9):

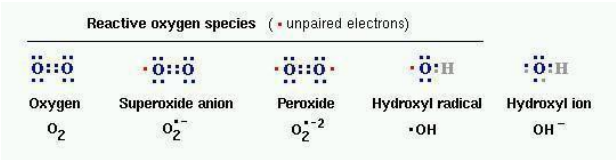


**Figure 9** Reactive oxygen species (model from colorado state university).

These unpaired electrons give ROS molecules unstable configurations. Every molecule has an outer shell of electrons termed as the valence shell. Molecules like to have their electron shell completely filled with electrons because this configuration grants stability to the molecules. ROS steal electrons from the stable compounds from the body to make them unstable and generate more free radicals, creating oxidative stress in the body. Therefore, ROS are very dangerous and are involved in the initiation of over 100 diseases.[43]

Superoxide anions ($O2.^-$) are formed when an oxygen molecule accepts one additional electron. This oxygen is reduced to superoxide anions as shown in equation

**$O2 + e^- \rightarrow O2^{\cdot-}$ - - - (i)**

**Superoxide anion is further reduced to H2O2 (equation #ii) or oxidized back to**

**$O2. O2 + 2e + 2H^- \rightarrow H2O2$ - - - (ii)**

**Citation:** Vasudeva WC. Breath is life yogic breathing is highest protection to life. *Int J Complement Alt Med.* 2022;15(3):177–189.
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H2O2 is a strong oxidizing agent and can be easily converted to most reactive and damaging hydroxyl radical (· OH).[45]

### B-6 Hydroxyl radical anion (.OH)

The hydroxyl radical, ·OH, is the neutral form of hydroxide ion $OH^-$. Hydroxyl radicals are highly reactive and short lived (Half-life $\cong 10^{-9}$ seconds).[45] Because of its reactivity, it immediately removes electrons from any molecule in its path, turning that molecule into a free radical and so propagating a chain reaction. Hydroxyl radical can damage all types of macromolecules such as carbohydrates, nucleic acids, lipids, and amino acids. This makes it very dangerous to the organisms. In Heber-Weiss process,[36] the hydroxyl radicals are generated from hydrogen peroxide in presence of ferric ions..

**$Fe^{3+} + O2^- \rightarrow Fe2+ + O2$ - - - (iii)**

**$Fe^{2+} + H2O2 \rightarrow Fe^{3+} + OH^- +. OH$ - - - (iv)**

Ferric ions in the human body are present in the red blood cells. The process of oxidation in the human body damages cell membranes. When oxygen is metabolized, it creates free radicals from other molecules causing damage to the body cells. Free radicals are unstable and react rapidly with other compounds available in the same vicinity and capture their electrons to become stable. Also, by losing electrons, these compounds also become free radicals and a chain reaction is set up which finally results in disruption of living cells and causes various diseases such as heart disease, different cancers, arthritis, lung disease, diabetes,[46] Parkinson's and Alzheimer's diseases, autoimmune diseases, eye diseases, and aging, etc.

Hydroxyl radicals play as a main role in the oxidative destruction of impurities in the body and is therefore sometimes called as a detergent.

## C. Benefits of pranayama proved scientifically

### C-1 Formation of carbon dioxide and carbonic acid in the body

It is well known that yogic breathing enhances health and aids healing. During yogic breathing exercises oxygen consumption is increased above normal. This increases the metabolic rate which is manifested by greater intake of oxygen. Yogic breathing exercises increase the consumption of oxygen with minimum physical exertion, under the conditions probably favorable to the storage of oxygen.[47] The blood takes up oxygen and releases carbonic acid generated from the waste products and poisonous matter, which has been gathered up by the blood from different parts of the system. The purified blood is caused by the four pulmonary veins to the left auricle and thence to the left ventricle. From the ventricle it is pumped into the biggest aorta. From aorta, it passes into the different arteries of the body. It is estimated that in a day 35,000 pints of blood traverses the capillaries of the lungs for purification.

During the process of pranayama, carbon dioxide is eliminated in large quantities and is found in the body as carbonic acid. Carbon dioxide is a waste product of the metabolism but is very essential for the body. It is carbon dioxide that tells the hemoglobin to release oxygen to the tissues. If over-breathing is done, it will bring down the carbon dioxide levels and the oxygen will not be delivered to the body cells and tissues. This will result in a lack of oxygen and suffocation, which will affect blood flow in the brain and heart. Therefore, pranayama is very important as it controls the breath and results in normal levels of carbon dioxide and oxygen in the blood.

### C-2 Hyperventilation and role of CO2 formed during

**Yogic breathing exercises**

Hyperventilation is caused because of the over-ventilation of the lungs which results when too much carbon dioxide is blown out, leaving behind too little CO2 in the body. When the carbon dioxide level in the blood drops too low, the cells and tissues of the body get very little oxygen and thus are unable to function well even though there may be plenty of oxygen in the blood. Extreme hyperventilation results in extremely low levels of CO2 in the blood and causes loss of consciousness and even death.

High levels of CO2 in the blood are usually accompanied by an increase in breathing so that CO2 levels come back to normal. In such conditions lips under tongue become blue due to a lack of oxygen. High levels of CO2 can also cause drowsiness or produce headache.

Lack of oxygen in the body cells produce lactic acid and free radicals. Low levels of oxygen in the body are caused by heavy breathing and low levels of CO2 in the lungs. Cell hypoxia (deficiency of CO2 in the cells) is the main cause of free radical generation and oxidative stress.

Normal people breathe about 12 L/min, while the medical norm is 6 L/min. This over breathing lowers blood CO2 levels to below normal and lead to deficiency of O2 in cells and tissues. Mouth and chest breathing also promote free radical damage and oxidative stress becomes the reason for the death of some severely sick and elderly people who feel miserable in the morning hours and die.

Yoga science of breathing is called pranayama (yogic breath control). The best time for its practice is early morning (≅ 4:00 am) when the pollution is at its lowest level and UV radiation from the sun are not around. Breathing exercises are done on an empty stomach. These are the conditions when very little or no free radicals are generated in the system. Pranayama should be done outside preferably in an open place where fresh air is available in abundance. Pranayama techniques are helpful in treating stressrelated disorders and in reducing oxidative stress. Pranayama causes change in the respiratory system and lowers the blood pressure. Intake of oxygen during pranayama makes the blood richer and renews the body tissues. Our body cells need to receive oxygen and return carbon dioxide, the waste product of metabolism within the cells. The lungs pass oxygen from the air we inhale into the bloodstream which is carried into the cells, The blood stream also carries the waste gas (CO2) which takes place of oxygen in the air sacs (alveoli) bringing the alveolar levels of CO2 to normal and the lungs exhale out extra CO2 on out-breaths. Normal levels of CO2 protect us against the problems of hyper and hypoventilations. A large supply of oxygen is needed for the combustion of food products leading to their oxidation and this is available while doing pranayama.

CO2 influences the viscosity of blood. Acute hyperventilation and arterial hypocapnia make blood more viscous. Although higher blood viscosity is more helpful in preventing blood loss during bleeding, it is dangerous for the heart as it may produce blood clots.

### C-3 Acid/Alkaline balance and the immune system

Carbon dioxide is dissolved in the blood where it is taken up by the red blood cells and is converted to carbonic acid in presence of carbonic anhydrase enzyme. The natural conversion of carbon dioxide to carbonic acid is a relatively slow process; however, carbonic anhydrase, a protein present in the red blood cell, catalyzes this reaction with sufficient rapidity.[48] Most of the carbonic acid then dissociates to bicarbonate and hydrogen ions.

**$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow HCO^- 3+ H^+$ - - - (v)**

**Citation:** Vasudeva WC. Breath is life yogic breathing is highest protection to life. *Int J Complement Alt Med.* 2022;15(3):177–189.
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This acts as a buffer solution. A buffer solution is one that maintains its pH. fairly constant even upon addition of small amounts of acid or base. Blood pH is tightly controlled between 7.35 to 7.45 (slightly alkaline) by some buffers in the body. If blood pH drops below 7, it can lead to coma or even death due to severe acidosis. If blood pH exceeds 8, this may also lead to death.[49] Hyperventilation (lack of CO2) is the most common cause of respiratory alkolysis and has following symptoms: dizziness, tingling in the lips, hands, or feet, headache, weakness, fainting, etc.[50]

## C-4 Anti-pollutant Action of CO2

Carbon dioxide when dissolved in water forms carbonic acid which dissociate into $H^+$, $HCO3^-$ and $CO_3^{2-}$ radicals. Carbonate radicals are formed when. OH, reacts with carbonate or bicarbonate ions.

**CO3 2- +. OH → CO3. - + OH - (I)**

**HCO3 - +. OH → CO3. - + H2O (ii)**

Carbonate radical is a potent one – electron oxidizing agent ($E^{01}$ = 1.78V) and oxidizes range of biomolecules including hyaluronic acid. It can abstract $H^-$ from cysteine.

**cys-SH + $CO3^{-\cdot}$ → cys-s· + $HCO3^-$** (iii)

However, $CO3^{-\cdot}$ radical is less damaging to proteins lipids and DNA than. OH.

It has the capability to oxidize the impurities and pollutants of the system. However, more work is needed to be done in this direction.

## C-5 Pranayama reduces the risk for the formation of kidney stones

Oxalic acid in the body binds with calcium to form kidney stones. Oxalic acid is an organic compound and is classified as a simplest dicarboxylic acid and has acidic and chelating properties. It occurs naturally in many vegetables and plants.[45] These include spinach, rhubarb, cocoa, chocolate, tea, beer, peanut butter, green beans, beets, collards, eggplant, sweet potatoes, blueberries, raspberries, and certain nuts. It causes burns, nausea, severe gastroenteritis, vomiting, shock, and convulsions. It forms kidney stones when combined with calcium. As little as 5 to 15 grams of oxalic acid may be fatal to humans.

If someone is at high risk for kidney stones, lowering the amount of oxalate in the body might be helpful and reduce the risk. Pranayama exercises (breath control) are very useful in this connection. Excessive oxygen inhaled through pranayama process is partially converted to ·OH radicals by Haber-Weiss reaction.[51] Haber-Weiss reaction is catalyzed by Iron ions which are normally obtained from red blood cells in the body.

·OH radical is a strong oxidizing agent and oxidizes oxalic acid[52] (or oxalate ion) according to the following equation:

**$C2O4^{2-}$ +. OH → $C2O4^-$ + $OH^-$**

↓ **(i)**

**CO2 + $CO2^{-\cdot}$**

CO2-. Free radical is powerfully reducing and converts O2 to more O2.-.

**$CO2^{-\cdot}$+ O2 → $O2^{-\cdot}$+ CO2** **(ii)**

Formation of $CO2^{\cdot -}$ free radical as an intermediate during the oxidation of carboxylic acids has been confirmed by electron spin resonance method.[53] The oxidation of oxalic acid by peroxydisulphate was also done by T.L. Allen[54] L.K. Saxena and C.P. Singhal[54,55] These authors proposed $SO4^{-\cdot}$ as reactive oxidant but later D.A. House.[55] indicated in his review that $SO4^{-\cdot}$ and ·OH free radicals have same effects as $SO4^{-\cdot}$ radicals are instantly hydrolyzed to. OH as soon as they are generated.

**$SO4^{-\cdot}$ + H2O → $HSO4^-$ +. OH** (iii)

## C-6 Yoga and weight loss

Yogic breathing enhances health and aids healing. Dr. Kovoor T. Behanan in his still-pertinent scientific evaluation of yoga, 1937, reported oxygen consumption in Kapal bhati, bhastrika, and Ujjayi pranayamas as 12.0, 18.5, and 24.5 percent respectively.[56] The consumption of oxygen during yogic breathing is a characteristic of yoga. Breathing has an important role in metabolism, the process by which body uses nutritive elements. The blood takes up oxygen and releases carbonic acid gas generated from the waste products and poisonous matter in the body which has been gathered up by the blood from all parts of the system. The carbonic acid decomposes into CO2 and water. The carbon dioxide is partially exhaled through the nose and is responsible for the weight loss.

It is known that weight loss is possible if kapal bhati is done regularly for some time every day. An attempt has been made to calculate weight loss based on the following facts –

(i) Kapal bhati pranayama is done regularly every day for 20 minutes at 20°C (or at 68°F).

(ii) In normal breathing, a person takes in about 600 ml of air while the vital capacity for an average person is 3,800 ml. Vital capacity is the maximum amount of air a person can expel from the lungs after maximum inhalation.

(iii) Analysis of the inhaled and exhaled air shows that former to be composed of 20.95% oxygen, 0.05% carbon dioxide, and 79% nitrogen; and the exhaled air of 16.5% oxygen, 4.0% carbon dioxide and 79.5% nitrogen.

(iv) Gaseous laws can be applied to the above gases consumed and formed, the volumes of these gases can be converted at NTP by Boyles and Charles laws by using the gas equation P1V1/ T1 = P2V2/ T2.

(v) The atmospheric pressures and the pressure at NTP (normal temperature and pressure) are the same i.e.760 mm Hg.

(vi) The volumes of the gases formed and consumed at NTP can be converted into weight by Avogadro's law which states "One gram mole of all gases occupy a volume of 22.4 liters at NTP".

(vii) The breathing rate for humans is assumed to be 15 breaths per minute.

Assuming vital capacity during kapal bhati pranayama as 3,800 ml and using above composition of inhaled and exhaled air (#(iii) above), the volumes of O2 consumed and CO2 & N2 liberated at NTP can be calculated as –

Inhaled air: 796.1 ml O2 + 1.9 ml CO2 + 3,002 ml N2
Exhaled air: 627 ml O2 + 152 ml CO2 + 3,021 ml N2
Therefore oxygen consumed = 169.1 ml

CO2 exhaled = 150.1 ml

N2 exhaled = 19.0 ml

Converting these volumes of O2, CO2, and N2 at NTP by the equation.

P1V1/ T1 = P2V2 / T2

if P1 = P2 = 760 mmHg, the equation becomes –

V1 / T1 = V2 / T2 (Charles' Law)

If kapal bhati is done at 20°C (or 68°F), then the above equation becomes

V1/273=V2/293

Using the above volumes of O2, CO2, and N2 as V1, their volumes can be calculated of NTP (V2) as 157.6, 139.8, 17.70 ml respectively for O2, CO2, and N2. These volumes can be converted to weights by using Avogadro's Law as – (Molecular weight in gms. / 22,400) x (volume at NTP).

The weight O2, CO2, and N2 were found as 0.2251, 0.2746, and 0.0221 respectively. It should be remembered that O2 is absorbed by the body while CO2 and N2 are exhaled.

Therefore, weight loss per breath

=0.2746 + 0.0221 – 0.2251

=0.0716 g = 71.6 mg

There are 15 breaths per minute, the weight loss per minute will be 1.074g. If kapal bhati is done for 20 minutes in one day, the weight loss per day will be 21.48g.

If kapal bhati is done regularly for 20 minutes per day, the weight loss per month will be 644.4gm (or 1.421 lbs.) and per year will be 7,732 gm (or ≅ 17.05. lbs) These calculations are approximate but still give us some insight into the weight loss during kapal bhati.

## C-7 Yogic breathing in cardiovascular diseases

It was found that some pranayama exercises, if done for a short time, reduce HR SBP pulse pressure, mean arterial pressure with a significant fall in diastolic pressure.[57-59] Satish Sivasankaran, M.D. while training at Yale said that Volunteers taking six weeks of yoga meditation program improved blood vessel function by 17%. He further said yoga and meditation are often recommend as a way to relieve stress.[60]

## C-8 Yoga reduces stress and anxiety, calms the mind, and removes depressive disorders

A number of studies have shown that yoga helps to reduce stress and anxiety and enhance the mood and overall sense of wellbeing.[61] Yoga manages depressive disorders.[62] Hatha yoga is an effective technique for enhancing mindfulness and decreasing stress levels in practitioners.[63]

Yoga is a mind-body practice that combines physical poses, controlled breathing, and meditation or relaxation.[91] Yoga reduces stress,[64] lowers blood pressure and heart rate,[11] and calms the mind.[64] Breath control is an important part of yoga. Controlling breathing can help to control the body and quieten the mind.

## C-9 Yoga reverses diabetes, protects against cancer, detoxifies the body, and lowers the cholesterol levels: a chemo preventive method

**According to the journal of Yoga and Physical therapy**

*"Yoga improves glucose levels even in cases of severe diabetes. It can keep blood pressure and cholesterol levels under control. It is important to keep in mind that yoga includes breathing exercises. This is one of the reasons that many consider it to be the best exercise for diabetes".*

**Diabetics-weekly:** Diabetics-weekly.com/yoga-best-exercise-diabetics/

Our digestive system breaks down our food into several nutrients including a sugar called glucose. It is then absorbed into blood stream and enters the cells with the help of a hormone called insulin. Glucose enters the blood from the liver or intestine. Insulin enters the blood stream from the pancreas. Insulin binds to a cell that need energy and opens the cell to glucose to enter.

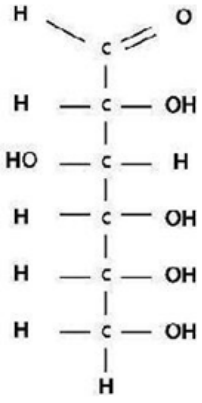
Sometimes our body makes not enough or no insulin or the body cells do not respond in the right way to the insulin in the blood. This means glucose has trouble entering the cells and hence remains in blood. This builds up to higher and harmful levels of glucose in the blood stream and is called hyperglycemia and results in diabetes. These high levels of glucose damage the blood vessels and lead to the complications of heart attack, stroke, kidney damage, blindness, nerve damage, and risk of limb loss (amputation).

The cells of the body need oxygen which is one of the constituents of air. During breath control exercises (pranayama), we breathe in – inhale – to bring in fresh supplies of air to the lungs which take the oxygen from it. We breathe out –exhale – to get rid of other gases in the air that the body does not need, as well as waste gases that the body has made during its functions. It should be remembered that during pranayama exercises the vital capacity of the lungs goes up to 3800ml[11] which supplies with high quantity of oxygen. Oxygen is carried to the cells through the blood. If the blood has high contents of glucose, then it is partly oxidized depending on the available quantity of oxygen in the blood. This reverts back the diabetes as it lowers the glucose levels in the blood. Bhastrika and kapal bhati are rapid cleansing processes and the oxygen consumption in the body during these pranayamas is 12.0% and 18.5%[65] over the normal breathing. This consumed oxygen is partially converted to. OH free radical by Haber-Weiss reaction (Section B-4.2; equations iii and iv) which oxidize the glucose to some extremely useful products.

## C-10 Analysis of reaction products

Glucose molecule can be chemically represented as:

The oxidation of glucose by ·OH radical anion was studied in details.[66] The reaction was found to be a chain reaction involving




several sequent and consecutive reactions. The order of this reaction was found to be 1.2.[67] which indicated that in order to oxidize one molecule of glucose at least five molecules of oxygen are required. Standard solutions of glucose and potassium peroxydisulphate were heated together at 60°C for about 5 days till the reaction was completed.

The reaction mixture was distilled under diminished pressure so as to prevent the escape of any volatile products. The residual and volatile fractions were analyzed for product identification which are summarized below.[68] It is known that peroxydisulphate ion in aqueous solutions decomposes to give two $SO4^{-}$ radicals which instantaneously hydrolyze to form $^{\cdot}OH$ radicals according to the following equations.[69]

**I.** $S2O8^{2-} \rightarrow 2SO4^{-}$ aq. soln

**II.** $SO4^{-} + H2O \rightarrow HSO4^{-} + \cdot OH$

## C-11 Identification of products

The products formed during the oxidation of D(+) glucose with ·OH radical anion are summarized below:[70]

**Non-volatile products:** Products identified in non-volatile fraction of the reaction mixture were found to be –

(i) gluconic acid (ii) glucuronic acid (iii) glucaric acid (iv) D-glucono-1-4-lactone

**Volatile fraction**: Formic acid and Formaldehyde were detected which seem to be formed as a result of C-C oxidative cleavage in glucose molecule.

The products clearly indicate that oxidation of D- glucose by ·OH radical anion is not confined to one group and oxidation of the aldehyde as well as the primary hydroxyl occurs concurrently. There is also oxidative cleavage of C-C bonds, giving rise to the volatile compounds of low molecular weight. In order to establish the mechanism of oxidation of glucose, several other simple compounds containing similar groups like polyhydric alcohols (glycol, glycerol, and sorbitol)[71] glyoxal,[72] glycolic acid,[73] and DArbinose[74] were studied.

## C-12 Usefulness of the products formed

### C- 12.1 Gluconic acid CH2OH· (CHOH)4· COOH

It is mild acid neither caustic nor corrosive. It is non-toxic and biodegradable organic acid of great interest. Gluconic acid and its derivatives are used in formation of pharmaceuticals, cosmetics, and food products as additives or buffer salts.[75] Aqueous solutions of gluconic acid contain glucono delta lactone which chelates metal ions and forms stable complexes. In alkaline solutions, it exhibits strong chelating activity towards calcium, iron, aluminium, copper, and other heavy metals, and removes some undesirable and unwanted metals from the body.

### C- 12.2 Glucuronic acid: CHO (CHOH)4 COOH

It is formed when glucose is oxidized. Its formation takes place in the liver of all animals including humans. The main function of this acid is to combine with drugs, toxins, and hormones and either carry them to different parts of the body or eliminate them. Glucuronic acid also assists in biosynthesis of ascorbic acid in the body. Since glucuronic acid is part of natural detoxification process in the body, it removes harmful toxins and is used in the treatment prostate cancer.

### C-12.3 Glucaric Acid: COOH·(CHOH)4·COOH

Glucaric acid is a sugar acid derived from D-glucose in which both aldehydic carbon atom and the carbon atom bearing the primary hydroxyl group are oxidized to carboxylic acid groups.[76]

Calcium D-glucarate is a chemical which is similar to naturally occurring chemical called glucaric acid. Glucaric acid is found in our bodies as well as in fruits and vegetables. Calcium D-glucarate is made by combining glucaric acid with calcium to make supplements that people use for medicine.[77] It enhances the glucuronidation, a process by which the body rids itself of potentially dangerous carcinogens and other harmful chemicals.

According to Dr. Thomas Slaga*,[1] "calcium D-glucarate is a substance that aids in glucuronidation, which is one of the body's major detoxification systems for eliminating both foreign chemicals and androgenous chemicals such as steroids and sterols.

Glucuronidation is a reaction where a toxin is made water-soluble so that it can be more easily excreted in the urine or bile. Calcium-D glucarate inhibits the detoxification – reversing enzyme Beta-Glucuronidase and it inhibits the 'bad enzyme' in the detoxification process". He further said D-glucarate has been shown to decrease lung, skin, liver, breast, and colon cancers by 60% or more.

### C- 12.4 D – Glucono 1-4 Loctone J

D – Glucono 1, 4 lactone is one of the metabolites of D – Glucaric acid and has the ability to prevent the activity of glucuronidase and increase the excretion of toxic compounds. It is a conjugate of D – glucono 1, 4 lactone (one of the identified products).

According to the National Center for Biotechnology Information – D – glucaro 1, 4 lactone is a delta lactone in which hydroxy group in position 6 has been oxidized to the corresponding carboxylic acid. It is a conjugate of a glucono 1, 4 lactone."

(National Center for Biotechnology Information, National Library of Medicine pubmed.nebi-nih.gov/compound/D – glucaro – 1, 4 – lactone).

Thus D – glucono 1, 4 lactone with further reaction with .OH is converted to D glucono 1, 4 lactone which is a very useful product for liver detoxification.

### C- 12.5 Metabolism

In presence of stomach acid, d-glucaric acid is metabolized to D-glucaro-1, 4lactone (30 % of ingested glucaric acid), D-glucaro-6, 3-lactone (30% of ingested glucaric acid), remaining D-glucaric acid.

Glucuronidation is liver's normal process of attaching a glucuronic acid molecule to harmful substances to detoxify and eliminate them from the body.

During liver detoxification certain hormones and various toxins undergo glucuronidation and are excreted through the bile or urine.

Ca D-glucarate's detoxifying and chemo preventive properties enable it to enhance glucuronidation and allowing the harmful compounds to be excreted. However, beta-glucuronidase enzyme has the capability to unbind these toxins which are reabsorbed and thus their excretion is stopped. D-glucaro 1,4-lactone (one of the metabolites of D-glucaric acid) has the ability to prevent this activity of B-glucuronidase and increase the excretion of toxic compounds.

### C-12.6 Lipid lowering

Calcium-D-Glucarate lowers cholesterol by 12%, LDL by 28%, and triglyceride by 43% in humans.[78] CDG decreases stress on the liver which lowers our need for cholesterol, specifically LDL.

### C-12.7 Volatile products

The volatile products found in this fraction were identified as formaldehyde and formic acid which are supposed to be formed as a result of C-C cleavage in the glucose molecule. The cleavage path was quantitatively estimated as 5% of the total reaction.[67]

A search of the literature shows that the formaldehyde and formic acid both are dangerous compounds. Formaldehyde is used[79] as an industrial fungicide, germicide, and disinfectant and as a preservative in mortuaries. Formaldehyde is the irritant of the eyes and causes sensitization dermatitis.[80] Prolonged exposure to formaldehyde may cause cancer in humans and therefore has been classified as a human carcinogen.

Formaldehyde is dangerous at higher concentrations.

*Dr. Thomas Slaga is the President/CEO and the chair of the center for cancer causation and prevention at the AMC Cancer Research center in Denver, Colorado.

**According to the American Cancer Society:[81]**

*"The main way people are exposed to formaldehyde is by inhaling it. The liquid form can be absorbed through the skin. People can also be exposed to small amounts by eating foods or drinking liquids containing formaldehyde. Enzymes in the body break down formaldehyde into formate (formic acid), which can be further broken down into carbon dioxide. Most inhaled formaldehyde is broken down by the cells lining the mouth, nose, throat, and airways, so that less than a third is absorbed by the blood".*

**American Chemistry Council writes in its "formaldehyde overview"[82]**

*"Formaldehyde is found in every living system – from plants to animals – to humans – produced as normal metabolic process. Formaldehyde is a naturally occurring substance made of carbon, hydrogen, and oxygen. Humans produce 1.5 ounces of formaldehyde a day as a normal part of our metabolism. Inhaled formaldehyde is rapidly metabolized and ultimately converted to carbon dioxide and exhaled. Formaldehyde does not accumulate in the body".*

Alternatively, the following mechanism is proposed by the author for the oxidation of formaldehyde to formic acid and formic acid to carbon dioxide and water. This mechanism is based on the following facts:

(i) Hydroxyl free radicals (˙OH) are generated in the body by Haber-Weiss process (modified by Fenton).[83]

(ii) Hydroxyl/free radicals (·OH) are extremely reactive (Half-life ≅ 10-9 seconds) and are capable to abstract hydrogen atom from C-H in formic acid[45] (or formaldehyde) to generate free radicals.

(iii) These free radicals are hydrolyzed to form corresponding hydroxy compounds which further decompose to CO2 and H2O.

**HCHO + ·OH →·CHO + H2O (i)**

**(Formaldehyde)**

**·CHO + H2O → OH-CH+·H (ii)**

**·H + ·OH → H2O (iii)**

**OH-CHO → HCOO- + H+ (iv)**

**(Formic acid)**

The formate radical is further decarboxylated as according to the following equation

**·OH + $HCOO^-$ → H2O + $CO_2^-$ (v)**

The carbon dioxide radical is powerfully reducing and converts oxygen to superoxide.[51]

**$CO2^{\cdot-}$ + O2 → CO2 + $O2^-$ (vi)**

The presence of $CO2^{\cdot-}$ in the system was detected by e.s.r method.[52]

Thus, pranayama exercises (breath control) help to reverse diabetes, decrease risk of cancer, detoxify the body, ensure healthy liver function, and lower LDL and total cholesterol levels.

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## Conflicts of interest

The author declares there are no conflicts of interest.

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