Chapter 1

INTRODUCTION
From the definition of prāṇayāma: prāṇa means vital force, ayāma means length or expansion (Iyengar, 2001). It is evident that these practices involve voluntary regulation of breathing. Two separate neural mechanisms regulate respiration (Ganong, 1987). One is responsible for voluntary control and the other for automatic control. The voluntary system is located in the cerebral cortex and sends impulses to the respiratory motor neurons via the corticospinal tract. The automatic system is located in the pons and medulla, and the motor outflow from this system to the respiratory motor neurons is located in the lateral and ventral parts of the spinal cord. Spontaneous respiration is produced by rhythmic discharge of motor neurons that innervate respiratory muscles, for e.g., the motor neurons to the expiratory muscles are inhibited when those supplying the inspiratory muscles are active, and vice versa. See the Figure from Nunn, (1975) on the next page. These rhythmic discharges are regulated by alterations in the arterial partial pressure of oxygen and carbon dioxide and hydrogen ion concentration as well as non chemical influences. Respiration can be voluntarily inhibited for sometime, but eventually the voluntary control is over ridden. The point at which the breathing can no longer be voluntarily inhibited is called the ‘breaking point’ and is due to the rise in the arterial partial pressure of carbon dioxide and fall in the partial pressure of oxygen.
In yoga voluntary regulation of breathing i.e. prāṇayāma, the cortical controls are used to overcome the automatic mechanism:

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\text{cale vāte calāṁ cittāṁ niscale niścalāṁ bhavet.}
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yogī sthanuṭvamāṇoti tato vāyuṁ nirodhayet.
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(Haṭha Yoga Pradipīkā: 2.16)

“When vāyu (breath or air) moves, citta (the mental force) moves. When prāṇa is without movement, citta is without movement. By this (steadiness of prāṇa) the yogi attains steadiness and should thus restrain the vāyu.”
Prāṇayāmas can be categorized as different types based on the physiological processes involved. For e.g., the physiological modulation may take the form of holding the breath along with certain maneuvers (bandhās or locks) as in kumbhaka prāṇayāmas. While generally inhalation is an active process and exhalation is passive, in bhastrikā (meaning bellows), both inhalation and exhalation are active processes. In other cases the practice may involve certain physiological maneuvers (partially closing the glottis as in ujjāyi which means victorious) (Swami Niranjananda Saraswathi, 1994). The other categories of prāṇayāma practices include those which have been studied in the present thesis. These involve nostril manipulation. Hence the practice may involve breathing in and out through the right nostril (sūryānuloma viloma), in and out through the left nostril (candrānuloma viloma) in contrast to sūrya bheda where inhalation is through the right nostril and exhalation is though the left nostril (Swami Muktibodhananda Saraswati, 1995). With alternate nostril breathing the breath cycle commences with exhalation through the left nostril and ends in the same way, this is nādiśuddhi (meaning subtle energy channels). All normal individuals have regular shifts in nostril dominance with a periodicity of 1–6 hours. This means that the dominant nostril through which we breathe shifts from one to the other every one to six hours and is hence recognized as an ultradian rhythm. The cycle as well as its variance is produced by alteration in autonomic tone of the nasal vasculature and reportedly correlates with a number of ultradian rhythms. The pacemaker of the nasal cycle is believed to lie within the
suprachiasmatic nucleus of the hypothalamus (Mirza, Kroger & Doty, 1997), which in turn receives input from the eyes via retino-hypothalamic fibers and hence entrains various body rhythms to the 24 hour light-dark cycle (Ganong, 1987). The nasal cycle reportedly correlates with a number of ultradian rhythms including asymmetric cerebral electroencephalographic (EEG) activity and differential performance on visual-spatial psychological tasks. These correlations will be detailed below. The phases of the nasal cycle and other ultradian rhythms have been associated with activities such as work (hunting), rest (healing), eating and many other behaviors that are required to meet primary bodily needs. These activities are defined as the basic rest activity cycle (BRAC) (Klietman, 1961). Experiments on human and non-human species showed that hyperventilation through the nose (as opposed to oral breathing) produced an activating effect on the electrographic activity in the cortex (Kristof, Servit & Manas, 1981; Servit, Manas & Strejckova, 1981). It was observed that the electrographic activity is produced by a reflex mechanism in the superior nasal meatus. This activating effect was elicited by air insufflation into the upper nasal cavity without pulmonary exercise. This effect was found to be suppressed on anesthetizing the mucosal membrane.

Wernitz, Bickford, Bloom and Shannahoff-Khalsa (1983) have proposed that the right nostril dominance correlates with the 'activity phase' of the BRAC and the left nostril dominance correlates with the 'resting phase' of the BRAC. The same authors (1983) showed that the nasal cycle is coupled to an alternating lateralization of cerebral hemispheric activity in humans. In this study it was observed that the EEG amplitudes were greater in the hemisphere contralateral to the dominant nostril.
Klein and Armitage (1979) first observed the ultradian rhythms of alternating cognitive performance efficiency by studying verbal and spatial skills and noted ultradian rhythm variations with a major peak of activity every 90-100 min. They observed that adult volunteers whose right nostril was dominant at the time of testing performed better in verbal tasks related to left hemisphere activity. Similarly left nostril dominance was correlated with better performance in spatial tasks inferred to be related to right hemisphere activity. In another study Klein, Pilon, Prosser and Shannahoff-Khalsa (1986) used both verbal and spatial cognitive tests to assess performance efficiency during different phases of the nasal cycle. They observed a significant relationship between the pattern of nasal airflow during normal breathing and performance on spatial and verbal tasks Right nostril dominance correlated with enhanced verbal performance, or left hemispheric activity and left nostril dominance correlated with enhanced spatial performance, or right hemispheric activity.

While these studies correlated the relationship between the nasal cycle during spontaneous breathing and various ultradian rhythms, it was interesting to understand the effect of unilateral forced nostril breathing (UFNB) on these rhythms. A study by Werntz, Bickford, Bloom & Shannahoff-Khalsa (1983) on the integration of EEG amplitudes and UFNB showed that UFNB produces a relative increase in the EEG amplitudes of the contralateral hemisphere. Correlating EEG changes with cognitive functions, a study on spatial and verbal task performance was done using breathing through dominant uninostril and forced uninostril breathing (Klein, Pilon, Prosser & Shannahoff-Khalsa, 1986). This showed that there was a tendency for subjects exhibiting baseline right nostril dominance to perform verbal tasks better (relative to
spatial performance) than subjects exhibiting left nostril dominance. However there was no effect of forced uninostril breathing on both verbal and spatial task performance. These results showed that at least in baseline (not forced breathing) conditions the function of the contralateral hemisphere is enhanced.

As described earlier there exist yoga breathing techniques involving breathing through the right, the left or alternate nostril breathing. The effects of three prāṇayāma techniques involving right-, left-, and alternate nostril yoga breathing were studied in normal adults who practiced all three techniques for a month as 27 breath cycles, four times a day (Telles, Nagarathna & Nagendra, 1994). Following a month of right nostril yoga breathing there was a significant increase in oxygen consumption (37%) whereas following left nostril yoga breathing there was an increase in galvanic skin resistance (137.7 kilohms). These results suggested that breathing through a particular nostril selectively influences the divisions of the autonomic nervous system. Following forty five minutes of right nostril yoga breathing the immediate effect was increased oxygen consumption (17%), systolic blood pressure (9.4 mm Hg) and increased cutaneous vasoconstriction (Telles, Nagarathna & Nagendra, 1996). Alternate nostril yoga breathing showed a trend of increase in the high frequency component of the heart rate variability spectrum which is believed to be related to an increase in the parasympathetic tone (Raghruraj, Ramakrishnan, Nagendra & Telles, 1998).

Another study was conducted to study the effect of alternate nostril breathing on the brain electrical activity using electroencephalograph (EEG) (Stancak & Kuna, 1994). It was shown that in the initial period of this practice (10 min) there was an
increase in the beta1 \((12.1 - 16.0 \text{ Hz})\) power and beta 2 \((16.4 - 30.0 \text{ Hz})\) power pointing to increased cortical excitability whereas prolonged practice showed an increase in the power of the alpha band suggesting cortical synchronization. In this study emphasis was given to the balancing effect of alternate nostril breathing in relation to beta1 band in both hemispheres showing general cortical excitability occurring during forced alternate nostril breathing without any special topographic preference relative to the direction of the nostril airflow. In another study middle latency auditory evoked potentials (MLAEPs) from the right and left hemispheres were recorded in subjects who practiced right nostril yoga breathing for thirty minutes compared to practicing breath awareness for the same duration (Raghuraj & Telles, 2004). The results showed that the peak amplitudes of two negative components of MLAEPs i.e., the Na wave and the Nb wave increased significantly during the right nostril yoga breathing compared to breath awareness. The Na wave corresponds to the activity at the mesencephalic-diencephalic (i.e., thalamus) level and the Nb wave corresponds to the activity at the dorso-posterior-medial of the Heschl’s gyrus, i.e., the primary auditory cortex. This suggests that the right nostril yoga breathing practice brought about effective activation of diencephalic and primary auditory cortical generators on the right hemisphere.

The cognitive performance of 108 school children who practiced right-, left-, and alternate nostril yoga breathing was assessed in verbal and spatial memory tasks (Naveen, Nagarathna, Nagendra & Telles, 1997). This study showed an improvement in spatial memory scores following all yoga breathing practices irrespective of nostril manipulation, suggesting a right hemisphere activating effect.
The consistent and selective effect of uninostril breathing on the autonomic nervous system and brain hemispheric activity suggests that uninostril breathing may have therapeutic value. Shannahoff-Khalsa & Beckett (1996) studied the clinical efficacy of yogic techniques in the treatment of 8 adults with OCD over one year follow up. Left nostril yoga breathing with voluntary nostril manipulation for 31 min was given along with other yoga practices. Patients showed a significant improvement in Yale-Brown Obsessive Compulsive scale (Y-BOCS), symptom checklist, Perceived Stress Scale and a significant reduction in medication. This makes it desirable for the effects of these nostril manipulation pranayamas to be understood in normal volunteers.