The universe we live in is periodic and therefore it is no surprise to find oscillatory processes in living organisms. Rhythms of varying frequencies are found at all levels of biological organization. In humans as brain waves oscillate with periods of milliseconds, one complete cycle of heart action takes about 0.8 seconds. Variations in body temperature and blood pressure undergo a periodicity of 24 hours. Hormone levels fluctuate daily, monthly and seasonally. In
living organisms several hundreds of various variables show periodicity. Lower as well as higher frequency rhythms also characterize the prokaryotic cell (Halberg and Conner, 1961; Eagon, 1962; Strutevant, 1973).

Period ranges for terms describing biologic rhythms (Halberg et al., 1977). However, most information is available for the 24 h rhythms; the circadian (from the latin Circa, approximately; dies, a day) cycles have been studied in detail from Escherichia coli (Halberg and Conner, 1961; Klebsiella (Strutevant, 1973) and Vibrio natriegens (Eagon, 1962) to man (Scheving et al., 1978; Lloyd, 1988).

Circadian cycles show a periodicity of 24 \(\pm 4\) h. Rhythms with a frequency lower than 1 cycle per 28 h are designated as infradian (Halberg et al., 1977). Circaseptan \((\tau = 7 \pm 3\) d), circadiseptan \((\tau = 14 \pm 3\) d), circavigintan \((\tau = 30 \pm 5\) d) and circannual \((\tau = 1\) y \(\pm 2\) m) rhythms come under the infradian category. Rhythms with a frequency higher than 1 cycle per 20 h are designated as ultradian. Objective quantification and investigation of the mechanism of biological rhythm fall in the domain of a new discipline called chronobiology (Halberg et al., 1977).

Under natural conditions circadian rhythms of any organism are entrained to the environmental cues, such as lightdark cycle and temperature cycle etc. These environmental cues are known as zeitgebers or synchronizers. For example, under such periodic condition most of the organisms exhibit circadian rhythms with periods exactly corresponding to the periods of the zeitgebers/synchronizers. This phenomenon is termed as synchronization. However, in the absence of these cues rhythms are found to be persisting but their period length deviates from precisely 24 h. The rhythm drifts out of synchrony with the environment characterized by lengthening or shortening of period. This state is called free running. This term, coined by Earl Bakken, and it came from physics where it was used for oscillations of pendulum.
(Halberg et al., 1986). Presence and persistence of the free running rhythm indicate that the biological rhythms are intrinsic and inside the body there may be centers which control these rhythms. These centers may be considered as circadian oscillators. Sometimes they are referred as circadian clocks or more loosely biological clocks.

In teleosts (Kavaliros, 1979), amphibians (Demain and Taylor, 1977), lizards (Underwood and Menaker, 1976, 1981) and in birds (Gaston and Menaker, 1968; Gaston, 1971; Menaker and Zimmerman, 1976; Underwood and Menaker, 1970) pineal has been considered as the center for the control of the rhythms. Studies on hamsters and sheep indicate that the duration of night time melatonin release is crucial. This probably helps interpreting photoperiod as a long or short day (Turek et al., 1983, 1984; Carter and Goldman, 1983; Binkley, 1988; Bittman et al., 1983). However, the diurnal rhythm in melatonin production is regulated by the suprachiasmatic nucleus (SCN) (Turek et al., 1983, 1984). In rats and hamsters PVN lesions disrupt the normal diurnal fluctuations in pineal melatonin and N-acetyl transferase (NAT) activity (Bittman et al., 1983; Klein et al., 1983).

In mammals, suprachiasmatic nucleus (SCN) of the hypothalamus region in the brain has been considered as the circadian oscillators (Moore and Eichler, 1972; Stephan and Zucker, 1972). Closer examination of neuro-endocrine systems further showed that SCN deletion obliterates the major circadian rhythms governing the release of anterior pituitary hormones including that of LH in spayed estrogen primed animals (Hery, 1977), ACTH (Szafarczyk et al., 1981a, 1981b, 1983), TSH (Jordon et al., 1979) and prolactin (Dunn et al., 1980). Furthermore Albers et al. (1981) have reported that lesions of suprachiasmatic nuclei in primates causes gradual
decay in the rhythm of drinking behaviour. Circadian rhythm of food intake in male Wistar rats has been known to be disrupted following bilateral suprachiasmatic injection of Naloxone (Reghunandan et al., 1988). However, several circadian rhythms persist even after bilateral lesion of the suprachiasmatic nucleus (SCN-S) (Assenmacher, et al., 1987). At present it would be highly speculative, therefore, to call SCN as the sole circadian oscillator.

It has been observed by Halberg that the characteristics of heart rate rhythm in human identical twins reared apart found to be the same in both the individuals (Halberg et al., 1986). This provides a clue that the characteristics of the rhythms are inherited. In addition it was thought that genes may be responsible for controlling the biological rhythms (Ehret, 1980). Konopka and Benzer (1971) have found that the gene called per gene for the period, coded for protein in the cell that regulates rhythms. Three clock mutants have been isolated and the mutations have been mapped in the per (period) locus located on the X chromosome: arrhythmic per0, short period per5 (Tau, τ = 19 h ) and long period per1 (Tau, τ = 28 h ) (Konopka and Benzer, 1971; Baylies et al., 1987). Recently frequency gene in Neurospora has also been identified, mapped and has been shown to share a sequence element with the Drosophila clock gene period (McClung et al., 1989). Furthermore, per gene sequence has been shown to be present in genomes of humans, mice and chickens. It is evident from the foregoing that the rhythms are integral part of life processes and our knowledge about organization in time is limited. Chronobiological research has great applied significance in medicine and in agriculture. Among other important applications, understanding of temporal organization of workers on a shift system is one of the major thrust areas of research in the domain of chronobiology. In a biological sense schedule-shift is single abrupt or gradual displacement of one or several events constituting a synchronizer.
schedule along the time scale of a period with which a given event recurs (Halberg et al., 1977). Since human mind and body have not been evolved to cope with shift-work during night hours, it is unlikely that night shift would not produce any harmful effects on human beings. Studies relating to schedule shift and biological rhythms are meagre. To evaluate the various effects of schedule-shift on human and other organisms it is essential to study the rhythms in several biological processes. Therefore, a lot of work has to be done, taking several biological end points and in a variety of species.

Under steady state conditions, circadian rhythm exhibits a typical phase relationship to the synchronizer (Aschoff et al., 1975). When the organism experiences a sudden shift of the synchronizer's phase, its rhythm appears desynchronized in the beginning but gradually resynchronization takes place and a constant phase relationship is achieved in relation to the altered phase of the synchronizer. The biological consequences of rhythm alteration have attracted attention of several workers. This part of the review provides a survey of important developments in our understanding of rhythm in animals and humans subjected to simulated and natural synchronizer shifts.

It has been well established that a shift of the zeitgeber induces comparable shift in the organism's rhythm (see reviews Pohl, 1978; Aschoff et al., 1975). In most of the experiments light : dark cycles or temperature cycles have been taken as zeitgeber. Meal timing (Nelson and Halberg, 1986a, b) and presence-absence (PA) cycles of the mother also act as zeitgeber. The PA cycles entrain circadian clocks of the pup (Viswanathan and Chandrashekaran, 1985a; Viswanathan, 1989). Their results clearly indicate that the developing animals during early days consider only
PA cycle of the mother as zeitgeber even though LD cycles are available.

The effects of zeitgeber phase-shift depend upon its direction. The time lag for re-entrainment of the biological rhythms also varies from species to species and depends upon the variable under investigation. Direction of re-entrainment in a 12 h shift depends upon whether light or dark period is doubled (Aschoff et al., 1975). Direction of re-entrainment after 12 h shift also depends upon the period (Hoffmann, 1969). The animals having period length shorter than 24 h in constant conditions follow synchronizer by an advance and those having period length longer than 24 h cycle follow the synchronizer by a delay (Pohl, 1978; Aschoff et al., 1975). Aschoff and Wever (1963) have observed that in case of birds the time lag for re-entrainment is shorter after an advance shift of the synchronizer than after a delay shift of the synchronizer. This has been described as the asymmetry effect (Aschoff et al., 1975). In contrast, the opposite has been reported for nocturnal rats. In diurnal lizards, Lacerta viridis (Fischer, 1961) and nocturnal flour beetle Tribolium confusum (Chiba et al., 1973) similar differences in the speed of entrainment after zeitgeber shift have been observed. Furthermore, alterations in the rhythmic activity of N-acetyl transferase to 8 hour shifts of the LD cycle have been observed; enzyme activity rhythm takes less time for re-entrainment following a delay shift than after an advance shift of the synchronizer (Illnerova et al., 1987). Apart from the motor activity rhythm, circadian rhythm in several other metabolic and endocrine parameters changes its phase following shifts of the synchronizer. Bhattacharya (1983) has described the heterogeneity in circadian phase shifting of some liver variables following reversal of L:D cycle. Furthermore, phase shift in mitotic rhythm of the corneal epithelium of rat has been observed by the reversal of light:dark cycle (Scheving et al., 1974a). In addition to this meal timing has also been considered as
a synchronizer responsible for phase-shifting the mitotic rhythm in mouse corneal epithelium. A comparison was made between light:dark cycle and meal timing, and light:dark cycle has been found as the strongest synchronizer (Scheving et al., 1974b). The strength of zeitgeber also exercises influence. It has been amply demonstrated for Gonyaulax (Hastings et al., 1958; Njus et al., 1974), Drosophila (Engelmann, 1969), Cockroach (Wobus, 1966), lizard (Hoffmann, 1969) and finch (Aschoff et al., 1975). A negative correlation between time needed for resynchronization and strength of the synchronizer has been observed for the chromatophore rhythm of fiddler crab as well as for the activity rhythm of ground beetles and fruit bats (see review Aschoff et al., 1975). The activity of rhythm of a lizard Lacerta sicula is also entrainable to a thermocycle. A 9 h shift of the temperature cycle has been shown to be followed by a comparable shift in the activity rhythm of L. sicula (Hoffmann, 1969). Further, effects of artificial 21 h or 27 h day as compared to 24 h day shorten the life span of fruit fly, Drosophila melanogaster (Pittendrigh and Minis, 1972). In addition to this Saint Paul and Aschoff (1978) have also demonstrated that the non-24-h day can have deleterious effects on survival of blowfly, Phormia terraenovae R.D. Effects of phase shifts on circadian rhythm and life span have also been discussed in rat by Nelson and Halberg (1986a, b). The life span modulating effects of phase-shift appears to be age dependent (Halberg and Nelson, 1976). The circadian locomotor rhythm of the mouse, Mus booduga has been shown to be entrained by red light/darkness (RD) cycles only when the light intensity is more than 150 μw/cm² (Viswanathan and Chandrashekar, 1985b).

Light plays an important role in phase resetting in sparrows (Binkley and Mosher, 1986) and in rats (Gander and Lewis, 1983). Furthermore, Van Reeth and Turek (1987) have reported that only a single injection of benzodiazepine, triazolam, to hamsters resulted in an approximately 50 percent reduction in the time taken for the circadian locomotor activity rhythm to be resynchronized to the new lighting schedule. There are several other agents that work
as phase resetters. However, this is outside the scope of this mini review.

On the basis of available information we can conclude that in almost all the studies single shift has been imposed and its effects have been analyzed, whereas in industries workers are usually exposed to weekly or monthly rotations of the work schedule. In certain places work schedule rotates still at a faster rate. However, in animal models information relating to repeated synchronizer phase-shifts is practically lacking.

Under natural conditions human circadian rhythms are usually synchronized with solar day. Basically humans are diurnal, remain active during day time and take rest during the night hours. There are, however, situations that result in a temporary deviation of the period from precisely 24 h and in disturbances of the temporal order. Such situations are given by transmeridian flight and by shift work during night. In both of these cases circadian rhythms are shifted by several hours. At the advent of modern industrialization continuous functioning of machines has become mandatory. Furthermore in hospitals, transport organizations, post office, security organization, etc. remain operational round the clock. Therefore, it is imperative that several workers would have to work during night. Keeping this point in view in industrialized countries work has been carried out to elucidate the effects of shift work on human health. The work relating circadian rhythm disturbances in jet pilots and shift workers has been briefly reviewed here.

Phase-shift of human circadian rhythms could be attributed to shift in artificial zeitgebers (Wever, 1980). Shifts in artificial zeitgebers are usually encountered during transmeridian flights. Sleep and circadian rhythms in rectal temperature and heart
rate of an air line pilot operating on a polar route has been investigated (Samel and Wegmann, 1988). It has been observed that the circadian system disturbed en route from West Germany to Japan via Anchorage. Probably irregular duty and sleep patterns magnify desynchronization. The re-entrainment of the circadian system has been known to depend upon the direction of flight (Aschoff et al., 1975). It has been reported that the eastward flights takes longer time to resynchronize as compared to westward flights. This has been gauged from the circadian rhythm in performance (Halberg and Nelson, 1976), depressed amplitude of oral temperature rhythm and from rhythm in the rate of oxygen consumption (Klein et al., 1972). Performance decreases strikingly in persons flying from West to East (Klein et al., 1970, 1972; Halberg and Nelson, 1976).

Shift workers are also exposed to shift in artificial zeitgebers. Shift work has been known to produce deleterious effects on the health of the workers. However, some workers can tolerate shift work better than others (Reinberg et al., 1980, 1983). Shift workers have been classified as tolerant or intolerant to shift work, based upon informations on sleep alterations, fatigue persistence, change in behaviour and digestive troubles (Reinberg et al., 1983). These authors observed circadian amplitude decrement in oral temperature rhythm of intolerant shift workers. Circadian amplitude decrement in oral temperature as well as pulse rhythms has also been documented in shift working Indian nurses (Pati and Saini, 1989). Desynchronization of oral temperature circadian rhythms with reference to mid-sleep timing has been found to be a common feature among shift workers (Reinberg et al., 1984). Work safety and productivity have been shown to be impaired on night shifts (Freivalds et al., 1983). In fact day sleeps of night-shift workers are
of reduced duration. On account of this a cumulative sleep debt may occur over a successive night shift. Thus this may influence productivity (Vidacek, et al., 1986). Adjustment to night shift depends upon the type of shift rota (Folkard et al., 1980), individual circadian phase position (Hildebrandt and Stratmann, 1979) and interindividual differences (Akerstedt, 1980; Reinberg et al., 1981, 1983). Foregoing review clearly indicates that the effects has been examined on some peripheral indicators. It is indeed very difficult to evaluate the effect of schedule shifts on internal rate processes in human beings.

It seems pertinent, therefore, to follow up on various basic findings on experimental animals for an optimization of human shift work. In the present study attempts have been made to evaluate the effect of repeated synchronizer phase-shifts on growth and circadian rhythms in core temperature, intermediary metabolites and hemopoietic variables in a domestic fowl Gallus domesticus. Experiments have been carried out to ascertain if chronosensitivity to different hormones is changing as a function of the direction of the repeated zeitgeber shifts. Although aves are endotherms, studies on this class of vertebrates relating to repeated schedule shifts are altogether absent. Studies available, so far, deal with researches on rodents and arthropods only. The present experimental model would also help us eliminating certain factors such as ectothermy versus endothermy and metabolic rate that might interact with results in a nonendothermic model. Since some information on mammals is available, results would allow comparison. En fin present investigation relating to growth, and circadian rhythms in intermediary metabolism as well as in erythropoiesis of domestic fowl would be of immense significance for the poultry. Eventually the results of the present work may provide some clue for optimization of schedule shift in human shift work for achieving the goal that concerns productivity as well as preventing deterioration of human health under productivity related mental and physical strains.