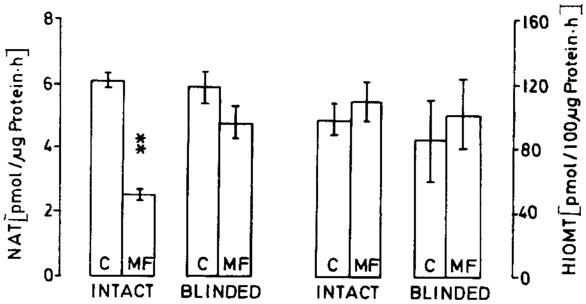

Fig. 1. Effects of an artificial earth-strength magnetic field on melatonin synthesis enzymes in pineal glands of pigeons (** $P<0.01$)

exposure to artificial MF, further supports this hypothesis. At mid-scotophase, when pineal melatonin content in pigeons peaks [8] and avian pineal NAT activity is high [9], a rotation of the MF's horizontal component results in decreased NAT activity in sighted pigeons thus paralleling the inhibitory effects of light [9] given to the lateral eyes which are connected to the pineal gland. If photoreceptors are responsible for magnetodetection – as predicted theoretically [10] – magnetic stimulation might mimic the inhibitory effects of light given to the lateral eyes on pineal melatonin synthesis in birds, as shown for mammals [2, 3]. Whether the pineal itself is affected by MF stimulation – as it is by light [9] – remains unclear as yet. The small reduction of NAT activity seen in the present study seems to point to an intrinsic sensitivity to MF; however, this effect lacks statistical significance. Interestingly, the electrophysiological response of single pineal cells to magnetic stimuli is also low in blinded pigeons compared to sighted animals [4]. Furthermore, assuming an MF effect in blinded pigeons, it cannot be ruled out that hypothalamic photoreceptors [11] also contribute to magnetoreception. Although decreased pineal HIOMT in quail has been shown following magnetic stimulation in vitro [5], it remains to be determined why pigeon HIOMT activity was not affected in the present study. This lack of response may be due to interspecies differences or to different experimental situations. Furthermore, in addition to photic input HIOMT regulation may also involve internal factors such as the hormonal milieu [12].

The results presented here provide further evidence that the avian pineal gland is sensitive to MF which may serve as an "additional zeitgeber" [13]. The mechanisms, however, by which an affected pineal metabolism might contribute to neuroendocrine processes, remain to be clarified.

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Magnetic-Field-Induced Skin-Temperature Changes of Animals Originate from Modified Air Convection

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Magnetic-field-induced skin-temperature changes have been reported for men [1], mice [2] and homing pigeons [3], but the physical and/or physiological origin of these a priori alarming effects has remained unclear.

It is known since over 60 years [4] that in paramagnetic gases pressure gradients set up when a magnetic field gradient (grad *H*) and a temperature gradient (grad *T*) are applied simultaneously. This is because both gas density ϱ and molecular paramagnetic susceptibility χ being proportional to T^{-1}, the magnetic force $\approx \chi \varrho H$ grad $H \sim T^{-2}$ acting on a volume element becomes inhomogeneous. This may result, at particular geometries, in convective flow and devices have been designed [5] where the cooling of a resistance caused by this flow is used as a direct measure of the concentration of molecular oxygen in air (as O_2 is the only paramagnetic component of ambient air).

Recently, we have demonstrated by flow visualization [6] and temperature measurements [7] in simple *vertical* convection cells (where a *horizontal* temperature gradient was maintained *without* animal) that free thermal convection of air is substantially modified in inhomogeneous magnetic fields by the very same mechanism: In typical solenoidal [7] or pole piece electromagnets [6] ($H > \approx 1$ *T*, grad $H > \approx 1$ *T*/

m) the magnetic force on O_2 becomes substantially [8] larger than the gravitational force. Therefore, gravitationally driven convective motion of O_2-containing gases including air [9] is generally modified inside such magnets at regions where the magnetic force overcomes gravitation: warmer parts of air, being less dense, and containing O_2 molecules with smaller χ, will be attracted less towards the region of maximum magnetic field than colder denser and more paramagnetic parts. As the temperature and field gradients are not parallel to each other in our geometry the differential body force between warmer and colder regions cannot be balanced by hydrostatic pressure everywhere and the resulting convective flow pattern reflects the symmetry of the field H grad H [6]. The same holds for the heat flow pattern and thereby for the pattern of the field-induced skin-temperature changes, as long as the skin is in sufficient thermal contact with the circulating air.

Although all our temperature measurements on pigeons [3] can be quantitatively accounted for by this mechanism [6, 7], a doubt may remain wether other (physiological) effects of magnetic fields are involved in the temperature changes.

We therefore carried out the same temperature measurements on pigeons as before [3], but by replacing the air around the pigeon's body by an Ar atmosphere. The pigeon's breathing was assured by filling the space around the head with air and separating it from the space below by a tight collar-type inset into the housing (at the level of the pigeon's neck). Figure 1 shows a typical temperature measurement taken at the breast under pure Ar, and after simple exchange of Ar against ambient air, about 20 min later [10]. Within our experimental resolution ($\approx$0.1 °C) the effect completely disappears under Ar. This clearly demonstrates that magnetic field effects other than the one described above, if they exist at all, do not significantly affect the skin temperatures.

The lack of magnetic field effects on heart and breathing frequency [3], oxygen content of the skin and oxygen uptake [11] of pigeons argues for the absence of other physiological effects. It appears probable that the temperature changes reported for mice [2] are also caused by modified convection of air: in fact, two attempts [12, 13] to reproduce the effect on rats have failed, both for skin temperatures [13] and rectal temperatures [12]. In these experiments [12, 13], and in contrast to the mice experiment [2], essentially closed, narrow plastic holders were used to maintain the animal in place, preventing skin contact with the convective air. We believe that magnetic-field-induced changes of thermal convection, as involving only modest field and temperature gradients, may also have been at the origin of some of the various other magnetic field effects on living organisms that have been reported.

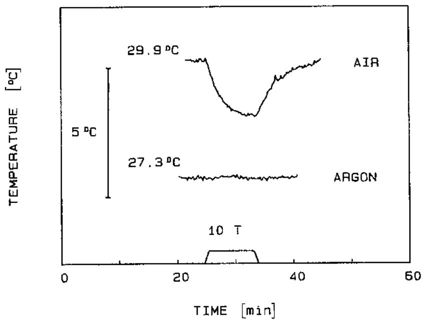

Fig. 1. Skin temperature at the breast of a pigeon exposed for 10 min to a magnetic field inside a solenoid with 10 T at the head. The space around the body was filled either with air or with argon

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8. χH grad $H/Mg \approx 100$ in the regions of highest H grad H in a 12 T split coil Bitter solenoid [6], $\chi = 3.45\ 10^{-3}$ cm^3 per mol O_2
9. For pure Ar or N_2, both diamagnetic, the convection is insensitive to the presence of magnetic fields of available intensities [4]
10. The difference between the starting (equilibrium) temperatures in both experiments originates from the use of a very slight continuous flow of (colder) Ar maintained to prevent leakage of air into the housing
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New Evidence for Validity of Haeckel's Law on Molecular Level

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According to the law of Haeckel – a basic law of biological evolutionary doctrine – embryonic development is a rapid recapitulation of evolutionary development. Recent success in sequencing hemoglobin chains (in some cases embryonic) from various organisms [1] makes it possible to check the validity of the above law on a molecular level. Some recent results suggest

