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Influence of radical pair reactions on biological rhythms

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9.1 Introduction

The concept of magnetoreception in animals is based on detecting weak magnetic fields by means of the magnetic field-dependent radical pair mechanism that occurs in the photoreceptors in eyes. Blue light sensitive cryptochromes engaged in this radical pair reaction are involved in synchronizing biological rhythms. This raises the possibility that weak magnetic fields may influence, or be made to influence, biological rhythms through the radical pair mechanism. This chapter analyzes the effect of magnetic fields on radical pair reactions, and discusses the likelihood of altering biological rhythms through these reactions. Our results show that, at zero and very weak magnetic fields (magnetic field, \( B << A \), where \( A \) is hyperfine coupling strength), the effect of hyperfine interaction is significant, thus increasing the magnetic field-dependent rate constant \( k_{isc} \). This rate constant \( k_{isc} \) decreases when \( B \) is somewhat higher than \( A \) (i.e., in medium magnetic fields) due to the Zeeman effect. At higher magnetic fields (\( B >> A \)) \( k_{isc} \) again starts to increase due to the \( \Delta g \) mechanism. The \( \Delta g \) mechanism provides an additional source of spin conversion if two radicals have slightly different \( g \)-factors (see Section 4.4). In addition, our results predict that the perturbation of chemical reaction rates in circadian rhythms changes the phase and concentration of these rhythms. The key words that sum up what this is about are biological effect, biological rhythm, magnetoreception, magnetic field-dependent rate constant (\( k_{isc} \)), radical pair mechanism and weak magnetic fields.

A magnetic field is produced by moving electrical charges, whereas an electric field is produced by stationary charges. The main characteristics of electromagnetic fields are their frequency and their strength. Electromagnetic fields of different strengths and frequencies influence biological systems in different ways. The electromagnetic spectrum is shown in Fig. 9.1. The high frequency waves (with lower wavelengths) have enough energy to ionize an atom or molecule. The low frequency