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ANALYTICAL CHALLENGE

Solution to the Olympic Games challenge

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The winner of the challenge (published in volume 404, issue 8) is:

Jennifer Dietz, Darmstadt, Germany

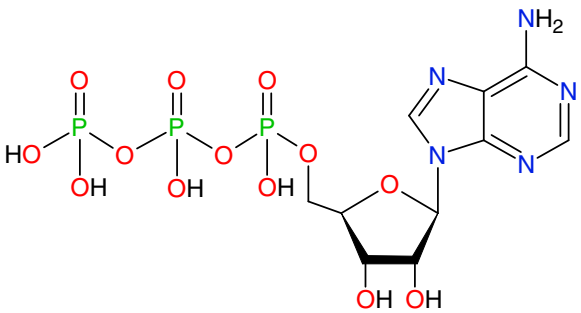
The award entitles the winner to select a Springer book of her choice up to a value of €75.

Our congratulations!

Solution

The solution to the Olympic Games challenge [1] is adenosine 5′-triphosphate (ATP; Formula 1). To be precise, the NMR spectra presented in the Olympic Games challenge [1] were measured from the more stable ATP disodium salt ($C_{10}H_{14}N_5Na_2O_{13}P_3$), but the spectra measured in D_2O are indistinguishable.

At the 2012 Olympic Games in London, Usain Bolt, the reigning Olympic champion in three Olympic events, ran the 100 m and 200 m with nearly the same average speed of 10.38 and 10.35 m/s. In contrast, Stephen Kiprotich—the 2012 gold medalist in the men's marathon—required 7,681 s for the 42,195 m. So, his average speed was "only" 5.49 m/s. Since endurance athletes are no less motivated than short-distance runners, the following question arises: Why must a marathon runner reduce his or her speed and run at almost half the speed of sprinters? The answer lies in the solution of this challenge, or more exactly, in the rate of synthesis of ATP in human muscle cells.



Formula 1 Adenosine 5′-triphosphate (all atoms in Olympic colors, with the exception of hydrogen)

The coenzyme ATP is the only direct fuel for muscle cells, regardless of whether an athlete is trained as a sprinter or as a marathon runner. The concentration of this direct fuel for muscles inside the cell is typically 1–10 mmol/L. Surprisingly, the total amount of ATP in working muscles is constant. Even extremely hard work does not lower the ATP concentration by more than about 20%. Several differing energy sources are used by working muscles to maintain the ATP level. During the short sprint period, the major driving forces are stored high-energy phosphates and anaerobic breakdown of glucose. Consequently, the 100 m sprinter can perform almost without breathing just by using the energy stored as ATP and creatine phosphate in the active

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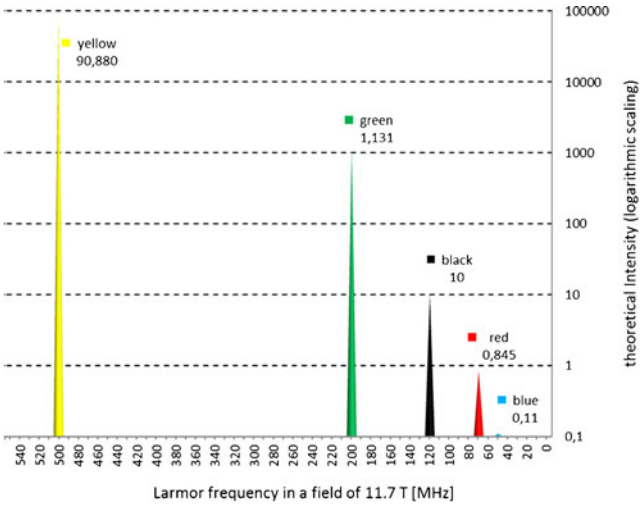

Fig. 1 The hypothetical NMR spectrum of isotopes of the five building nuclei of the compound. The presentation of the theoretical absolute intensities requires a logarithmic scaling

muscles. Within the first 30 s of strenuous activity, the reserves of phosphocreatine in skeletal muscle are emptied under anaerobic conditions. For this reason, sprinters are often large and very muscular people, in contrast to the lanky long-distance runners. In contrast, the energy supply for endurance-trained runners is primarily the glycogen stored in muscles for the first few minutes and then, for up to 3 h, blood glucose, and eventually fat. Whereas carbohydrates are hydrolyzed into simple sugars, such as glucose and fructose, triglycerides must be metabolized to give fatty acids and glycerol. Since this aerobic lipid metabolism is a much slower process than the direct phosphorylation of adenosine 5′-diphosphate by phosphocreatine or anaerobic glycolysis, long-term activities must progress at a slower rate than high-speed short-term activities.

In the Olympic Games challenge [1] the elemental composition of the substance of interest, ATP, was given in combination with the NMR spectra of the five different types of atomic nuclei to be found there. First, the five Olympic colors—black, yellow, blue, red, and green—had to be translated into the names of the five elements carbon, hydrogen, nitrogen, oxygen, and phosphorus by means of the spectral and verbal information. So, the figures in the Olympic Games challenge show the one-dimensional ^{1}H, ^{31}P, ^{13}C, and ^{17}O NMR spectra and the two-dimensional ^{1}H–^{15}N heteronuclear multiple bond correlation and ^{1}H–^{13}C heteronuclear single quantum coherence and heteronuclear multiple bond correlation spectra. Because of their low abundance, the ^{15}N nuclei were measured in a justifiable experimental time by indirect detection only (Fig. 1).

Reference

1. Meusinger R (2012) Anal Bioanal Chem 404:2113–2116