Hemoglobin - Adaptations to environmental and metabolic constraints, with special reference to temperature as modulating effector

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Hemoglobin (Hb) is paradigm for studying molecular mechanisms underlying adaptive traits. In transporting O_2 from respiratory surfaces to metabolizing tissues, it directly links aerobic metabolism with environmental conditions. Hb-O_2 binding is commonly cooperative (described by sigmoid shaped O_2 binding curves) and decreased by red cell allosteric effectors (protons, CO_2, lactate, organic phosphates and chloride anions) that modulate O_2 loading/unloading in response to changes in environmental and metabolic dictates. Given the exothermic nature of heme oxygenation, blood O_2 affinity is moreover decreased by rising temperature. Although this temperature dependence enhances O_2 unloading in warm tissues with increased O_2 requirement, it is potentially maladaptive in regionally-heterothermic animals, where it may hamper O_2 unloading in cold extremities (arctic mammals) or cause excessive O_2 release in warm organs (muscles, brains or eyes of fast-swimming fish).

Following brief illustration of key intraspecific adjustments in Hb-O_2 affinity (changes in the levels of allosteric effectors) and genetically-coded, interspecific adaptations (that commonly involve differences in Hb structure), the treatise focuses on reductions in the temperature sensitivities encountered in Hbs of regionally-heterothermic animals (including extinct woolly mammoths), and their molecular underpinnings, specifically enthalpic contributions from endothermic dissociation of effector ions that reduces the overall exothermy of Hb-oxygenation.