Energy Modeling in BioNetGen

# Introduction

The basic concept of energy modeling is to use thermodynamic quantities to specify the equilibrium and kinetic properties of biochemical reaction networks. The idea of using a rule-based formalism for such a specification came to my group from Vincent Danos, who around 2009 was working with Peter Swain and his student Julien Ollivier on the development of energy-based formalisms for biochemistry (1). Vincent visited my lab in 2010 and gave two lectures on the concept, which motivated several members of the lab to discuss the possible development of an implementation of energy modeling in the BioNetGen language (2). Inspired by discussions involving Leonard Harris, John Sekar, Jintao Liu, and myself (probably others as well), Justin developed a formalism and implementation of energy modeling that he described in detail in Chapter 2 of his thesis (3). This chapter remains the most complete description of the energy modeling capabilities of BioNetGen. More recently, John Sekar extended the description of the formal basis for the language and provided additional examples demonstrating how the energy formalism can be used to model the effects of cooperativity (4).

# Example Models

The quickest way to learn energy modeling is from the example models that have been developed. The current set of energy models is

1. energy\_example1.bngl — Fully annotated model describing the cooperative binding of three proteins to a scaffold protein.
2. mwc.bngl — Example from Sekar et al. the describes cooperative binding of oxygen to hemoglobin.
3. wofsy-goldstein.bngl — Example from Sekar et al. the describes cooperative binding of the epidermal growth factor (EGF) to its primary receptor (EGFR) according to the model of Wofsy et al. (5).
4. Kiefhaber\_emodel.bngl — Model for coupled folding and binding of a peptide to a ligand based on Kiefhaber et al. (6).

The files will be part of BioNetGen distributions 2.5.2 and later, and they can be accessed directly [through this GitHub link](https://github.com/RuleWorld/bionetgen/tree/master/bng2/Models2/EnergyModels).

# References

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5. Wofsy C, Goldstein B, Lund K, Wiley H. Implications of epidermal growth factor (EGF) induced egf receptor aggregation. Biophys J. 1992 Jul;63(1):98–110.

6. Kiefhaber T, Bachmann A, Jensen KS. Dynamics and mechanisms of coupled protein folding and binding reactions. Curr Opin Struct Biol [Internet]. 2012 Feb [cited 2014 Aug 9];22(1):21–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22129832