BioSystems 127 (2015) 14–27

Contents lists available at ScienceDirect

BioSystems

journal homepage: www.elsevier.com/locate/biosystems

Review

Biological wires, communication systems, and implications for disease

Douglas E. Friesen[a], Travis J.A. Craddock[b,c], Aarat P. Kalra[d], Jack A. Tuszynski[a,e,*]

[a] Department of Oncology, University of Alberta, Edmonton, Alberta T6G 1Z2, Canada
[b] Center for Psychological Studies, Graduate School of Computer and Information Sciences, College of Osteopathic Medicine, Nova Southeastern University, Ft. Lauderdale, FL 33314, USA
[c] Clinical Systems Biology Group, Institute for Neuro-Immune Medicine, Nova Southeastern University, Ft. Lauderdale, FL 33328, USA
[d] Department of Chemistry, Dayalbagh Educational Institute, Agra 282005, India
[e] Department of Physics, University of Alberta, Edmonton, Alberta T6G 2E1, Canada

ARTICLE INFO

Article history:
Received 17 September 2014
Received in revised form 30 October 2014
Accepted 31 October 2014
Available online 4 November 2014

Keywords:
Microtubules
Information processing
Actin
Collagen
Integrins
Signaling

ABSTRACT

Microtubules, actin, and collagen are macromolecular structures that compose a large percentage of the proteins in the human body, helping form and maintain both intracellular and extracellular structure. They are biological wires and are structurally connected through various other proteins. Microtubules (MTs) have been theorized to be involved in classical and quantum information processing, and evidence continues to suggest possible semiconduction through MTs. The previous Dendritic Cytoskeleton Information Processing Model has hypothesized how MTs and actin form a communication network in neurons. Here, we review information transfer possibilities involving MTs, actin, and collagen, and the evidence of an organism-wide high-speed communication network that may regulate morphogenesis and cellular proliferation. The direct and indirect evidence in support of this hypothesis, and implications for chronic diseases such as cancer and neurodegenerative diseases are discussed.

Contents

Abbreviations: MTs, Microtubules.

* Corresponding author at: Department of Oncology, University of Alberta, Cross Cancer Institute, 11560 University Avenue, Edmonton, Alberta T6G 1Z2, Canada. Tel.: +1 780 432 8906.
E-mail address: jackt@ualberta.ca (J.A. Tuszynski).

http://dx.doi.org/10.1016/j.biosystems.2014.10.006
0303-2647/

1. Introduction

Explaining the mechanism of coordination of the organism as a whole is still a major challenge in the field of biology. Methods of communication in the human body are commonly thought to include electrical signaling by the central nervous system, chemical signaling through blood plasma with hormones, and cytokine chemical signaling. Additionally, inter- and intra-cellular connections in the body, which form a structurally and mechanically connected link between the cytoskeleton, the nuclei of cell, and the extracellular matrix indicate the possibility for mechanotransduction with much faster speeds than traditional chemical signaling (Wang et al., 2009). Here we review these structures involving MTs, actin, and collagen, and consider them as bionanowires that form a mechanical tensegrity matrix throughout the body potentially capable of high-speed electrical, protonic, and ionic signaling. Bioelectrical signaling is involved in regeneration and ordering of the organism (Levin, 2003; Levin and Stevenson, 2012), and as chemical message passing systems have limited speeds, we review the evidence that an organism takes advantage of these bionanowires to attain faster message passing speeds.

The main theories for a body-wide information network based upon bionanowires come from the tensegrity work of Ingber et al. (2014), as well as the theories of Oschman, 1984, 2003, 2009 and Ho (1998), who have previously theorized submolecular (electronic, protonic, and ionic) communication systems in the body, and the work of Szent-Györgyi (1941, 1957) concerning the idea that proteins in organisms possess semiconducting properties. We take an in-depth look at information transfer possibilities involving microtubules (MTs), actin, and collagen in the organism. In essence, we extend the Dendritic Cytoskeleton Information Processing Model describing the role of MTs and actin in information processing in the brain (Priel et al., 2005a; Tuszynski et al., 2007; Woolf et al., 2009) to investigate the potential for a fully interconnected submolecular messaging passing system in the body as a whole.

2. Intercellular message passing

Conventional message passing systems include chemical and electrical signals passed through synapses and gap junctions, and autocrine, paracrine, and endocrine chemical signaling. However, it is becoming apparent that the entire organism is mechanically connected in an interconnected 'tensegrity' matrix that allows for long-range mechanotransduction (Ingber et al., 2014; Wang et al., 2009). The extracellular matrix, which defines the space between cells, forms connections to the cell's interior through integrins, which connect to the intracellular cytoskeleton. The cytoskeleton, in turn, connects to the nuclei of cells forming a continuous mechanical linkage (Fig. 1).

Mechanical stress-wave propagation through this structure can create signals that travel at least 40 times faster (Na et al., 2008) and potentially thousands of times faster than chemical signals that use diffusion or translocation (Wang et al., 2009). This connective matrix suggests the possibility of high-speed communication systems at work in the organism.

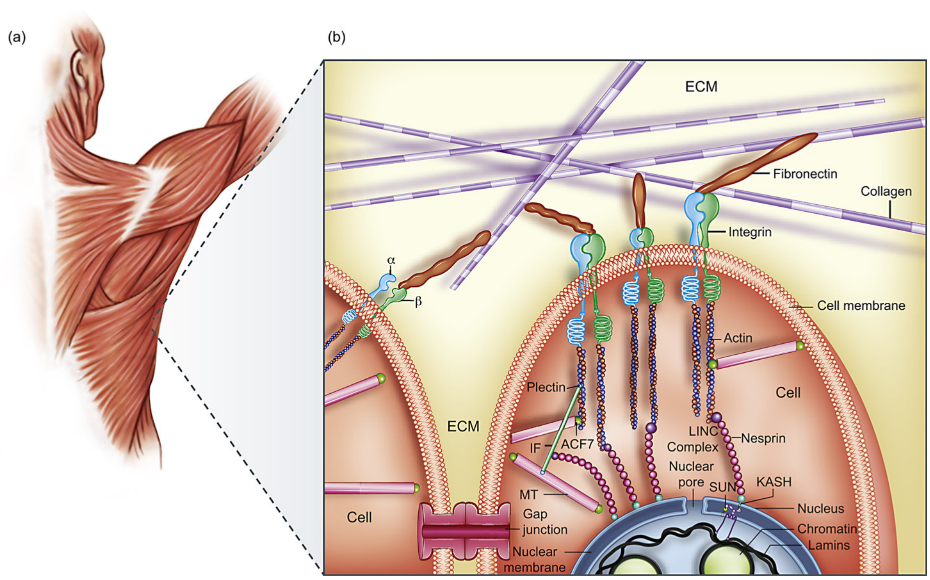

Fig. 1. The interconnected matrix of bionanowires. (a) Connective tissue forms a continuous network throughout the body. (b) Much of connective tissue is composed of a web-like collagenous matrix that forms an extracellular matrix between cells. Collagen, connected to fibronectin, integrins, the cytoskeleton, and the nucleus, form a mechanically coupled system. Mechanotransduction, as well as ionic, electronic, and protonic signals are hypothesized to be transmitted through this matrix.