Seminars in Cell & Developmental Biology 46 (2015) 135–142

Contents lists available at ScienceDirect

Seminars in Cell & Developmental Biology

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

Review

Gliding motility in apicomplexan parasites

Matthew B. Heintzelman*

Department of Biology, Bucknell University, Lewisburg, PA 17837, USA

ARTICLE INFO

Article history:
Received 8 July 2015
Accepted 25 September 2015
Available online 30 September 2015

Keywords:
Apicomplexa
Toxoplasma
Plasmodium
Myosin
Actin
Gliding locomotion

ABSTRACT

Apicomplexan parasites, including *Plasmodium* and *Toxoplasma*, employ a unique form of substrate-dependent locomotion known as gliding motility. In these obligate, intracellular parasites, gliding motility is used for migration through the tissues and cells of the host, for active penetration of the host cell, and, at times, for proactive egress from the host. Gliding motility is powered by an actin–myosin based motor apparatus, known as the glideosome, which is situated within the elaborate cortical domain of the parasite. In this system, myosin is anchored to an internal membrane complex and drives the rearward translocation of actin-associated cell surface adhesins, thus leading to forward movement of the parasite. This review outlines our current understanding of glideosome architecture and the molecular basis of parasite motility.

Contents

1. Introduction

Gliding locomotion in eukaryotic cells is an intriguing form of substrate-dependent cell motility employed by a rather small cohort of cell types [1]. Unlike cells that swim through an aqueous environment with the aid of cilia or flagella, or that traverse a substrate with the dramatic shape-shifting changes seen in amoeboid crawling, most cells that glide over a substrate do so without a traditional locomotory organelle and exhibit little morphological distortion as they move. Our understanding of the molecular mechanics by which gliding is accomplished is most advanced for the Apicomplexa, a diverse group of largely obligate intracellular parasites [2,3] that can employ gliding to migrate to their host cell and then, in many instances, actively propel themselves into that host within which they can then safely proliferate. Gliding motility in the Apicomplexa has been the subject of intense interest because many of these parasites cause significant morbidity and mortality in humans and other animals. Given the important role of parasite motility in the disease process, a clear understanding of its molecular mechanism may lead to the development of effective strategies for treatment or prevention of disease. Among the most well studied parasites in the phylum are the *Plasmodium* species, responsible for the devastating burden of malaria [4], and *Toxoplasma gondii*, another widespread pathogen and etiological agent of toxoplasmosis [5]. Nevertheless, information gleaned from experiments on a

* Correspondence to: Department of Biology, Bucknell University, 1 Dent Drive, Lewisburg, PA 17837, USA.
E-mail address: mheintze@bucknell.edu

http://dx.doi.org/10.1016/j.semcdb.2015.09.020
1084-9521/

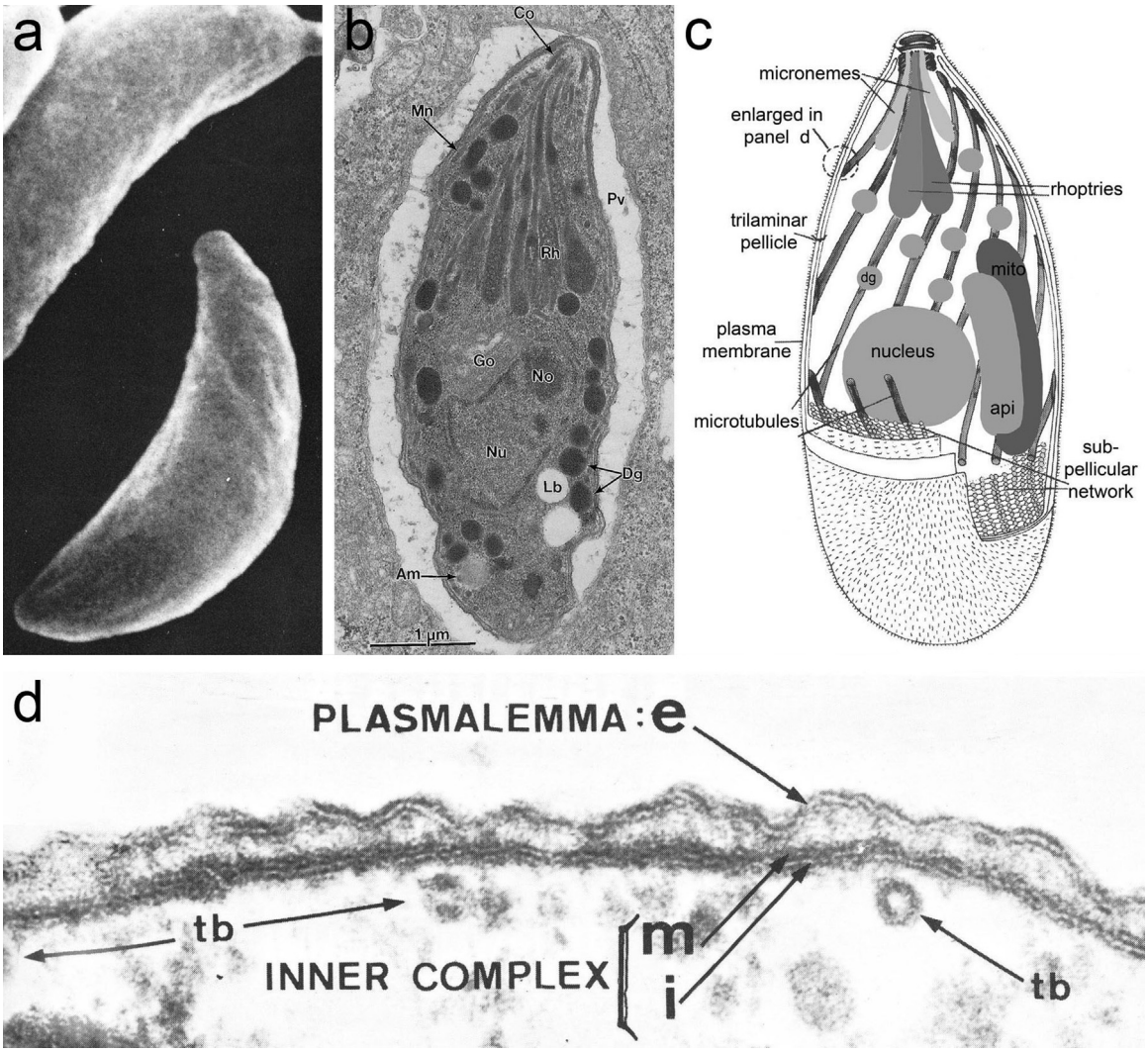

Fig. 1. Morphology of apicomplexan parasites and their cortical architecture. Scanning electron micrograph (a) of a *Toxoplasma* tachyzoite, with the apical pole pointing upward. Reproduced with permission from Chiappino et al. [137]. Transmission electron micrograph (b) of an intracellular *Toxoplasma* tachyzoite residing within a parasitophorous vacuole (Pv). The apical pole is at the top and the apical complex of organelles is evident. Reproduced with permission from Dubey et al. [138]. Schematic representation (c) of a prototypical apicomplexan zooite. Reproduced with permission from Fowler et al. [139]. Transmission electron micrograph (d) through the pellicle of an *Eimeria* sporozoite illustrating the plasma membrane and the subjacent inner membrane complex where the motor complex is anchored. Reproduced with permission from Dubremetz and Torpier [9].

number of related Apicomplexans, including *Eimeria*, *Cryptosporidium*, *Babesia*, *Theileria* and others, has contributed to our knowledge and allowed investigators to identify conserved features that serve to reinforce a generalizable model for motility [6], though variations do exist as one might expect among parasites exhibiting a variety of life cycle constraints. The discussion here is focused primarily on *Toxoplasma* and *Plasmodium*, but even then, space does not permit all of the species-specific variations to be described; rather, the goal is to provide an overview of the major themes and elements of motility and a framework for a more detailed understanding that will come with immersion in the primary literature.

2. Apicomplexan architecture

Some understanding of parasite architecture is important for appreciating both the morphological and the mechanistic aspects of gliding locomotion. The invasive forms of apicomplexan parasites, the zooites, share similar morphological traits, although the details vary both among species and also among different life cycle stages within the same species. A prototypical zooite (*e.g.* a *Toxoplasma* tachyzoite or a *Plasmodium* sporozoite) is a banana- or crescent-shaped cell on the order of 5–15 μm long and 2–5 μm wide depending on the species [7] (Fig. 1). The shape and functional integrity of the cell is dependent upon an elaborate cytoskeletal network that subtends a trilaminar membranous pellicle consisting of the plasma membrane and a subjacent platform of one or more flattened vesicles, the alveolar membranes, a feature that unifies the Alveolata [8–11] (Fig. 1d). The alveolar membranes, together with their cytoskeletal infrastructure, constitute the inner membrane complex (IMC) of the pellicle, a domain of the parasite that has received significant attention given its role in anchoring the gliding motor complex [12].

A prominent feature of the subpellicular cytoskeleton is an array of microtubules that extends from the apical polar ring, a microtubule organizing center, and twists toward the posterior pole of the parasite, interacting with the internal face of the IMC for about two-thirds of its length [9,13–16] (Fig. 1c). The structure of the IMC is then more intimately supported by a filamentous scaffold termed the subpellicular network which is comprised, at least in part, of a family of proteins known as alveolins [17–19]. In addition to these scaffolding proteins and the anchoring components of the motility apparatus that reside in the IMC, many additional proteins are