Discovery of myosin I and Pollard-san

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Abstract

In this short review, I describe a brief history of the discovery of myosin I isolated from *Acanthamoeba* in 1973 by Tom Pollard and Ed Korn. Today, myosins form a large “family tree” that includes more than 30 types of myosins. I discuss the importance of the relationship among actin, myosin, and other actin-binding proteins, many of which were pioneered by Pollard-san (“-san” is a Japanese honorific suffix showing respect, politeness and friendship). At the first conference devoted to actin, Pollard-san, Korn-san, and I discussed the importance of the nucleotide bound at the two ends of the actin filament. I conclude that life is a dynamic accumulation of molecule-molecule bindings, and although we do not yet know how they coordinate with each other to operate a living cell, many enthusiastic and excellent researchers like Pollard-san will unveil mechanisms that will show us what life really looks like.

Keywords Actin · Myosin · *Acanthamoeba*

Discovery of myosin I

Myosins have been purified from amoeba to mammalian muscles. In the 1960s, isolated myosins from slime mold were confirmed to bind to actin. Their functions were characterized by using further purified myosins (Adelman and Taylor 1969; Hatano and Ohnuma 1970; Hatano and Oosawa 1966; Hatano and Tazawa 1968). During that time, the typical methods used to characterize myosin were gel filtration, measurements of ATPase activity, and the ability of actin filament to assemble myosin using a range of salt concentrations.

Myosin I was discovered in *Acanthamoeba* by Pollard and Korn using improved methods (Pollard and Korn 1973). Its molecular weight was 40 kDa lower than that of other known myosins, and while it lacked the ability to

self-assemble, it did have an ATPase activity. When their paper came out, I thought that this *Acanthamoeba* myosin I was a kind of myosin II, only a bit smaller. One reason for this conclusion was that detailed experimental conditions and supporting information were not available at that time. Today, methods have greatly improved and there are many papers that provide finely detailed experimental information. However, at that time, Pollard-san’s careful investigations were already very important and helped us understand various cellular functions, especially for the membrane dynamics and trafficking (McIntosh and Ostap 2016). At present, more than 30 types of myosins are known (Thompson and Langford 2002; Foth et al. 2006; Odronitz and Kollmar 2007; Sebe-Pedros et al. 2014; de Souza et al. 2018), and I think that the discovery of myosin I by Pollard-san was the starting point for what the myosin family tree is now.

For me, the most memorable conversation with Pollard-san was at the 2nd International Congress of Biorheology held in Israel in 1974. We joined a tour to Golgotha Hill (today known as Calvary) and he told me the history of the hill. I was astonished by Pollard-san’s love of knowledge, which must be one of the driving forces for his excellence in research and discovery. This enthusiasm must have prompted him to characterize the interactions of actin with many actin-regulatory proteins including myosin and to understand the mechanisms of cell motility, especially the cell membrane protrusions propelled by actin polymerization (Pollard and Borisy 2003).

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Meeting with Pollard-san and Korn-san at an actin conference in Australia

To characterize the power stroke of actomyosin, conjugating fluorescent probes to proteins is a potent approach. Manuel Morales conjugated fluorophores to myosin in muscle fibers and measured the internal structural dynamics of actomyosin (dos Remedios et al. 1972). Years later, Cris-san (Cris dos Remedios) was traveling to Paris for a meeting to present his discovery that actin could form flat sheets and straight helical tubes in the presence of Gd (III) at low salt (dos Remedios and Dickens 1978). On his way to Paris, he happened to read Chapter 6 of my book *Thermodynamics of the Polymerization of Proteins* (Oosawa and Asakura 1975) and was amazed to find that I had already predicted that such structures would exist. Later he worked with Masao Miki in Sydney where they discovered additional binding sites for fluorophores to actin that proved important for understanding conformational dynamics of the actin molecule (Miki et al. 1987). It is worthy of note that Cris-san has tight bonds with many Japanese biophysicists since he joined Koshin Mihashi's lab in Japan by the support of The Matsumae International Foundation. Cris-san organized the first conference devoted to actin in Sydney in 1982 (dos Remedios and Barden 1983). Pollard-san and Korn-san were also at the meeting where we spoke about the importance of nucleotide states at both ends of actin filaments. I have a feeling that the meeting was the very first chance to make everyone consider the nucleotide states at both terminal subunits of actin filaments.

Conclusion

Life is a dynamic accumulation of molecule-molecule bindings, and still we do not know how they coordinate with each other to operate a living cell. Like Pollard-san, many enthusiastic and excellent researches will unveil the mechanisms of life and show us what it really looks like.

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Compliance with ethical standards

Conflicts of interest Fumio Oosawa declares that he has no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by the author.

References

- Adelman MR, Taylor EW (1969) Further purification and characterization of slime mold myosin and slime mold actin. *Biochemistry* 8: 4976–4988
- de Souza DAS, Pavoni DP, Krieger MA, Ludwig A (2018) Evolutionary analyses of myosin genes in trypanosomatids show a history of expansion, secondary losses and neofunctionalization. *Sci Rep* 8: 1376. <https://doi.org/10.1038/s41598-017-18865-y>
- Foth BJ, Goedecke MC, Soldati D (2006) New insights into myosin evolution and classification. *Proc Natl Acad Sci U S A* 103:3681–3686. <https://doi.org/10.1073/pnas.0506307103>
- Hatano S, Ohnuma J (1970) Purification and characterization of myosin a from the myxomycete plasmodium. *Biochim Biophys Acta* 205: 110–120
- Hatano S, Oosawa F (1966) Isolation and characterization of plasmodium actin. *Biochim Biophys Acta* 127:488–498
- Hatano S, Tazawa M (1968) Isolation, purification and characterization of myosin B from myxomycete plasmodium. *Biochim Biophys Acta* 154:507–519
- McIntosh BB, Ostap EM (2016) Myosin-I molecular motors at a glance. *J Cell Sci* 129:2689–2695. <https://doi.org/10.1242/jcs.186403>
- Miki M, Barden JA, dos Remedios CG (1987) Spatial relationship between the nucleotide-binding site, Lys-61 and Cys-374 in actin and a conformational change induced by myosin subfragment-1. *Eur J Biochem* 168:339–345
- Odrionitz F, Kollmar M (2007) Drawing the tree of eukaryotic life based on the analysis of 2,269 manually annotated myosins from 328 species. *Genome Biol* 8:R196. <https://doi.org/10.1186/gb-2007-8-9-r196>
- Oosawa F, Asakura S (1975) *Thermodynamics of the polymerization of proteins*. Academic, New York
- Pollard TD, Borisy GG (2003) Cellular motility driven by assembly and disassembly of actin filaments. *Cell* 112:453–465
- Pollard TD, Korn ED (1973) *Acanthamoeba myosin I. isolation from Acanthamoeba castellanii of an enzyme similar to muscle myosin*. *J Biol Chem* 248:4682–4690
- dos Remedios CG, Barden JA (eds) (1983) *Actin: structure and function in muscle and nonmuscle cells*. Elsevier Science Publishing Co Inc, San Diego
- dos Remedios CG, Dickens MJ (1978) Actin microcrystals and tubes formed in the presence of gadolinium ions. *Nature* 276:731–733
- dos Remedios CG, Yount RG, Morales MF (1972) Individual states in the cycle of muscle contraction. *Proc Natl Acad Sci U S A* 69:2542–2546
- Sebe-Pedros A, Grau-Bové X, Richards TA, Ruiz-Trillo I (2014) Evolution and classification of myosins, a paneukaryotic whole-genome approach. *Genome Biol Evol* 6:290–305. <https://doi.org/10.1093/gbe/evu013>
- Thompson RF, Langford GM (2002) Myosin superfamily evolutionary history. *Anat Rec* 268:276–289. <https://doi.org/10.1002/ar.10160>