MUSCLE

Regulating the Scallop

from our Molecular Biology Correspondent

ONE of the most interesting developments in muscle biochemistry in recent years is the partial resolution of the regulatory machinery, which enables the myosin ATPase to respond to small changes in the concentration of calcium supplied by the sarcoplasmic reticulum. In the mammalian systems, on which most of the work until just now has been done, the site of regulation is in the thin filaments, the effect of the calcium, which binds to one of the troponin subunits, being transmitted by way of the other troponin components and tropomyosin to the actin. This causes a change in the affinity of the actin for the myosin heads, reaching out towards it from the thick filaments. Szent-Györgyi and his colleagues have been looking at the muscles of more primitive creatures, and here it seems that regulation is encompassed in a totally different manner, and operates not at the thin filaments but rather the myosin heads. Szent-Györgyi, Szentkiralyi and Kendrick-Jones (*J. Mol. Biol.*, **74**, 179 ; 1973) now unfold a remarkable story concerning the mechanism of regulation of scallop muscle.

Fortune has to an extent favoured them, for the wily scallop has incorporated a regulatory subunit into its myosin, which, unlike the minor chains of numerous other myosins that have been looked at, can be removed without reducing the protein to an enzymatically inert porridge. The myosin extracted from scallop muscle is superficially indistinguishable from that of mammals: its hydrodynamic and optical rotatory properties are the same, and so is its length in the electron microscope, as well as the segment long spacing in fibres. When exposed to proteases under the right conditions it gives rise to enzymatically active soluble fragments, corresponding to heavy meromyosin and subfragment-1 (or isolated heads). Also like rabbit myosin, it contains light chains, which in SDS-gel electrophoresis come out at a molecular weight of about 18,000, and in a ratio of three chains per myosin molecule.

There are, it turns out, two types of light chain in the scallop, one of which contains cysteine and is present in a ratio of two copies per myosin. The other, of which there is only one copy per myosin molecule, is dissociated when EDTA is added to sequester divalent metal ions. It is this molecule which is the "regulatory subunit", in that it confers calcium response on the myosin. Thus, the ATPase activity is unaffected by the addition of calcium ions when the critical light chain has been stripped off, whereas the ATPase of intact myosin with its complement of light chains is strongly inhibited by removal of calcium. When the preparation of light chains is added back to the stripped myosin, the calcium sensitivity is restored. The stripped myosin still binds calcium, but binding plots indicate that probably one site has been lost. The light chain is not of itself, however, capable of taking up calcium. The other (cysteine-containing) light chains remain firmly stuck to the myosin, and their removal by more drastic methods leads to irreversible denaturation.

The independence of the thick and thin filament-dependent regulation mechanisms is spectacularly demonstrated by the interaction of the desensitized scallop myosin, denuded of its regulatory light chain, with the rabbit actin-tropomyosin-troponin system, with which it combines just like rabbit myosin to give a fully calcium-regulated actomyosin. This points again to the evolutionary stability of actin compared with myosin, at which evolutionary pressures are evidently mainly directed. Rabbit myosin will induce a high and calcium-independent ATPase activity in a mixture of actin with excess scallop myosin. It seems therefore that when there are no calcium ions about, the scallop myosin does not combine with actin, so that the actin filaments are available for reaction with a competing species. Neither, in consequence, is the ATPase of the scallop myosin stimulated by actin in the absence of calcium. Like the regulatory protein system of mammalian thin filaments, then, the sensitizing subunit of the scallop myosin blocks the interaction with actin. The oddest aspect of this engrossing story is the stoichiometry. In principle it is possible, with the aid of some allosteric hand-waving, to explain the calcium response of a system bearing a regulatory subunit on only one myosin head. The authors eschew such intellectual contortions, and postulate instead that the regulatory chain physically links the two heads, and functions only when so located. In support of this kind of scheme is the finding that active isolated heads (8–1) from the scallop myosin contain the regulatory light chain, but have no calcium sensitivity.

A curious twist to the picture of regulation in mammalian muscle emerges from an observation by Bailin and Bárány (*J. Biol. Chem.*, **248**, 373 ; 1973), who find that rabbit myosin, dinitrophenylated to the extent of 1.5 modifying groups per molecule, displays no calcium sensitivity in its complexes with actin, tropomyosin and troponin. Partial removal of the dinitrophenyl groups leads to reappearance of calcium sensitivity. This seems to indicate that the myosin when modified no longer recognizes the difference between the inhibiting and non-inhibiting states of the thin filaments.

SOLAR SYSTEM

Primordial Field

from our Geomagnetism Correspondent

THE strength of the interplanetary magnetic field is now of the order of tens of gammas. But has it always been so? And in particular, was it quite so low at the time of the origin of the Solar System? In the absence of any other information, it is often taken as axiomatic that the interplanetary field has always been negligible ; but Sonnet *et al.* (*Astrophys. Space Sci.*, **7**, 446 ; 1970) have postulated otherwise, and primordial magnetic fields of the order of 1 oersted ($10^5\gamma$) are apparently required by the cosmological theories of Fowler *et al.* (*Geophys. J.*, **6**, 148 ; 1962).

In principle, it should be possible to determine the intensity of the primordial interplanetary field from carbonaceous chondritic meteorites, for Banerjee and

Drag Reduction for a Rotating Disk

ALTHOUGH drag reduction in turbulently flowing liquids containing small amounts of polymers like polyacrylamide is fairly well investigated, both practically and theoretically, it is the possibility of drag reduction under conditions of laminar flow that is in many ways of particular interest. For one thing laminar flow is more commonly encountered than turbulent flow.

In next Monday's *Nature Physical Science* (March 12) Kale, Mashelkar and Ulbrecht show that drag can be reduced when a disk rotates under laminar conditions in an appropriate polymer solution. What they have done is to investigate the relationship between torque and angular velocity for disks between 7.5 and 15 cm in diameter in solutions of carboxy methyl cellulose—an inelastic fluid—and in three solutions of polyacrylamide of varying strength. It turns out that for a given angular velocity (plotted by Kale *et al.* as a moment coefficient) the torque is significantly reduced in the case of the polyacrylamide solutions.

Kale and his colleagues draw attention to the fact that others have shown drag reduction in laminar flow to be possible in situations like flow in a curved tube and flow round a sphere, but they place their own work firmly on a practical footing when they say that "for centrifugal pumps with enclosed disk-type impellers there is likely to be a better pumpability with viscoelastic liquids".