A “BLUE ENLIGHTENMENT” ERA IS DAWNING

THE ESTABLISHMENT OF THE EUROPEAN MARINE BIOLOGICAL RESOURCE CENTRE (EMBRC-ERIC) TO FURTHER THE GLOBAL RELEVANCE OF MARINE BIORESOURCES

IN THIS ISSUE

118 Dr Wilfred Alexander Chalamira Nkhoma from the World Health Organization details the priorities for tackling infectious diseases in Africa

224 Jan Wörner, Director General of The European Space Agency (ESA) speaks to us about his priorities for enhancing the competitiveness of the European space sector

300 Mareš Šefčovič, Vice-President, Energy Union at European Commission discusses establishing a European Energy Union
Developmental biology: Electrogenic cells in a gymnotiform fish

Graciela A. Unguez, PhD at Professor of Biology at New Mexico State University argues that electrogenic cells in a gymnotiform fish retain a skeletal muscle transcriptome, but they are not muscle cells in this fascinating example of developmental biology.

Embryological, molecular and genetic studies in vertebrates have revealed a highly conserved process of generating skeletal muscle cells. In all species of mammals, birds, fish, reptiles and amphibians studied to date, precursor cells are induced to differentiate to form skeletal muscle by the activation of a small number of core myogenic regulatory factors (MRFs) belonging to the MyoD family of transcription factors. All four MRF members, i.e., MyoD, myogenin, myf5 and MRF4/myf5, have been isolated and studied in different vertebrate embryos.

Although the number of copies of these MRFs and their temporal expression patterns during muscle differentiation can differ considerably between species, it is clear that formation of skeletal muscle cells requires MRFs. Parallel studies using different vertebrate systems are providing fundamental knowledge of the transcriptional and signalling mechanisms of the MRF-dependent myogenic programme.

Reports that some MRFs are detected in non-contracile cells like the electrical conductive cells of the heart (or Purkinje fibres) in birds and frogs, the myoid cells of the thymus and myofibroblasts in mouse and the electrogenic cells (or electrocytes) of the electric organ (EO) in electric fish are considered rare exceptions. We investigated the transcriptional regulation of the electrocyte phenotype by MRFs in the gymnotiform Sternoptyx macrurus. Specifically, we determined the expression profiles of target muscle genes with MRF binding sites tested for activation by MRFs.

Our analysis showed similar levels of these muscle transcripts in EO and skeletal muscle (Fig. 1). The detection of transcripts for these contraction-associated genes in EO was unexpected given that protein expression studies using mammalian antibodies against muscle creatine kinase, troponin-T and all isoforms of sarcomeric myosin heavy chain failed to detect these proteins in EO lysate (Fig. 1) and mature electrocytes (Fig. 2). We have also performed an expression analysis using qRT-PCR informed by deep RNA sequencing of transcriptomes of muscle and EO tissues from adult S. macrurus. Our data showed that:

- Components associated with the homeostasis of the sarcomere and sarcomere-sarcolemma linkage was transcribed in EO at levels similar to those in muscle; and
- MRFs associated with activation of the skeletal muscle programme were not differentially expressed between these tissues.

Together, these data indicate that the down-regulation of the muscle pheno-
type in EO is not predominantly controlled at the transcriptional level by MRFs. Instead, electrolytes in *S. macrurus* appear to have evolved from striated muscle cells wherein the muscle programme may be under the regulation of non-coding RNAs (long non-coding RNAs, microRNAs) to repress the gene expression that gives rise to the contractile phenotype.

**References**


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**Figure 2.** Muscle proteins in electrolytes of *S. macrurus*. Immunolabeling for muscle proteins (green) reveals staining of electrolytes (ECs) (arrow in a-actinin panel) for desmin, a-actinin, acetylcholine receptor (AChR), and laminin, but not for myosin heavy chain (MHC), muscle creatine kinase (MCK), or tropinin-I. Rat skeletal muscle fibers.

**Figure 3.** Overview of expression of transcripts associated with regulation of muscle gene expression in muscle and EO of *S. macrurus*. Electrocytes are large, cigar-shaped, multi-nucleated and do not contain sarcomeres, but express all transcripts that code for sarcomeric proteins, muscle-specific transcription factors, and protein-degradation genes at levels similar to those in muscle.

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