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Regulation of Specific Developmental Fates of Larval- and Adult-Type Muscles during Metamorphosis of the Frog *Xenopus*Keiko Shimizu-Nishikawa ... Akio Nishikawa¹ Show more<https://doi.org/10.1006/dbio.2002.0800>[Get rights and content](#)Under an Elsevier [user license](#)[open archive](#)

Abstract

During anuran metamorphosis, larval-type myotubes in both trunk and tail are removed by apoptosis, and only trunk muscles are replaced by newly formed adult-type myotubes. In the present study, we clarified the regulatory mechanisms for specific developmental fates of adult and larval muscles. Two distinct (adult and larval) types of myoblasts were found to exist in the trunk, but no or very few adult myoblasts were found in the tail. Each type of myoblast responded differently to metamorphic trigger, 3,3',5-triiodo-L-thyronine (T_3) *in vitro*. T_3 -induced cell death was observed in larval myoblasts but not in adult myoblasts. These results suggest that the fates (life or death) of trunk and tail muscles are determined primarily by the differential distribution of adult myoblasts within the muscles. However, a transplantation study clarified that each larval and adult myoblast was not committed to fuse into particular myotube types, and they could form heterokaryon myotubes *in vivo*. Cell culture experiments suggested that the following two mechanisms are involved in the specification of myotube fate: (1) Heterokaryon myotubes could escape T_3 -induced death only when the proportion of adult nuclei number was higher than 70% in the myotubes. Apoptosis was not observed in any larval nuclei within the surviving heterokaryon myotubes, suggesting the conversion of larval nuclei fate. (2) Differentiation of adult myoblasts was promoted by the factor(s) released from larval myoblasts in a cell type-specific manner. Taken together, the developmental fate of myotubes is determined by the ratio of nuclei types, and the formation of adult nuclei-rich myotubes was specifically enhanced by larval myoblast factor(s).

Keywords

myoblast; myotube; thyroid hormone (3,3',5-triiodo-L-thyronine); differentiation; programmed cell death (apoptosis); heterokaryon; metamorphosis; anuran; *Xenopus laevis*; *Xenopus borealis*

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References

REFERENCES

- 1 B. Antonsson, J.C. Martinou
The Bcl-2 protein family
Exp. Cell Res., 256 (2000), pp. 50-57
[Article](#)  [PDF \(120KB\)](#)

- 2 R.L. Chambers, J.C. McDermott
Molecular basis of skeletal muscle regeneration
Can. J. Appl. Physiol., 21 (1996), pp. 155-184
- 3 M. Cho, S.M. Hughes, I. Karsch-Mizrachi, M. Travis, L.A. Leinwand, H.M. Blau
Fast myosin heavy chains expressed in secondary mammalian muscle fibers at the time of their inception
J. Cell Sci., 107 (1994), pp. 2361-2371
- 4 M.G. Cusella-De Angelis, S. Molinari, A. Le Donne, M. Coletta, E. Vivarelli, M. Bouche, M. Molinaro, S. Ferrari, G. Cossu
Differential response of embryonic and fetal myoblasts to TGF beta: A possible regulatory mechanism of skeletal muscle histogenesis
Development, 120 (1994), pp. 925-933
- 5 G.F. Duglison, P.J. Scotting, P.M. Wigmore
Rat embryonic myoblasts are restricted to forming primary fibres while later myogenic populations are pluripotent
Mech. Dev., 87 (1999), pp. 11-19
[Article](#)  PDF (448KB)
- 6 D. Evans, H. Baillie, A. Caswell, P. Wigmore
During fetal muscle development, clones of cells contribute to both primary and secondary fibers
Dev. Biol., 162 (1994), pp. 348-353
[Article](#)  PDF (615KB)
- 7 Y. Gavrieli, Y. Sherman, S.A. Ben-Sasson
Identification of programmed cell death in situ via specific labeling of nuclear DNA fragmentation
J. Cell Biol., 119 (1992), pp. 493-501
- 8 M.O. Hengartner
The biochemistry of apoptosis
Nature, 407 (2000), pp. 770-776
- 9 A. Ishizuya-Oka, S. Ueda
Apoptosis and cell proliferation in the *Xenopus* small intestine during metamorphosis
Cell Tissue Res., 286 (1996), pp. 467-476
- 10 J.C. Kaltenbach
Endocrinology of amphibian metamorphosis
L.I. Gilbert, J.R. Tata, B.G. Atkinson (Eds.), Metamorphosis: Postembryonic Reprogramming of Gene Expression in Amphibian and Insect Cells, Academic Press, San Diego (1996), pp. 403-433
- 11 A.M. Kelly, S.I. Zacks
The histogenesis of rat intercostal muscle
J. Cell Biol., 42 (1969), pp. 135-153
- 12 J.F. Kerr, B. Harmon, J. Searle
An electron-microscope study of cell deletion in the anuran tadpole tail during spontaneous metamorphosis with special reference to apoptosis of striated muscle fibers
J. Cell Sci., 14 (1974), pp. 571-585
- 13 D.J. Mangelsdorf, C. Thummel, M. Beato, P. Herrlich, G. Schutz, K. Umesono, B. Blumberg, P. Kastner, M. Mark, P. Chambon
The nuclear receptor superfamily: The second decade
Cell, 83 (1995), pp. 835-839
[Article](#)  PDF (2MB)
- 14 K. Nakajima, A. Takahashi, Y. Yaoita
Structure, expression, and function of the *Xenopus laevis* caspase family
J. Biol. Chem., 275 (2000), pp. 10484-10491
- 15 P.D. Nieuwkoop, J. Faber
Normal Table of *Xenopus laevis* (daudin), North-Holland, Amsterdam (1967)
- 16 A. Nishikawa, H. Hayashi

Isoform transition of contractile proteins related to muscle remodeling with an axial gradient during metamorphosis in *Xenopus laevis*

Dev. Biol., 165 (1994), pp. 86-94

[Article](#)  [PDF \(760KB\)](#)

- 17 A. Nishikawa, H. Hayashi
Spatial, temporal and hormonal regulation of programmed muscle cell death during metamorphosis of the frog *Xenopus laevis*
Differentiation, 59 (1995), pp. 207-214
[Article](#)  [PDF \(1MB\)](#)
- 18 A. Nishikawa, M. Kaiho, K. Yoshizato
Cell death in the anuran tadpole tail: Thyroid hormone induces keratinization and tail-specific growth inhibition of epidermal cells
Dev. Biol., 131 (1989), pp. 337-344
[Article](#)  [PDF \(864KB\)](#)
- 19 A. Nishikawa, K. Shimizu-Nishikawa, L. Miller
Isolation, characterization, and in vitro culture of larval and adult epidermal cells of the frog *Xenopus laevis*
In Vitro Cell Dev. Biol., 26 (1990), pp. 1128-1134
- 20 A. Nishikawa, K. Shimizu-Nishikawa, L. Miller
Spatial, temporal, and hormonal regulation of epidermal keratin expression during development of the frog, *Xenopus laevis*
Dev. Biol., 151 (1992), pp. 145-153
[Article](#)  [PDF \(9MB\)](#)
- 21 A. Nishikawa, K. Yoshizato
Hormonal regulation of growth and life span of bullfrog tadpole tail epidermal cells cultured in vitro
J. Exp. Zool., 237 (1986), pp. 221-230
- 22 C.L. Pin, P.A. Merrifield
Embryonic and fetal rat myoblasts express different phenotypes following differentiation in vitro
Dev. Genet., 14 (1993), pp. 356-368
- 23 L.M. Sachs, B. Abdallah, A. Hassan, G. Levi, A. De Luze, J.C. Reed, B.A. Demeneix
Apoptosis in *Xenopus* tadpole tail muscles involves Bax-dependent pathways
FASEB J., 11 (1997), pp. 801-808
- 24 L.M. Sachs, S. Damjanovski, P.L. Jones, Q. Li, T. Amano, S. Ueda, Y.B. Shi, A. Ishizuya-Oka
Dual functions of thyroid hormone receptors during *Xenopus* development
Comp. Biochem. Physiol. B Biochem. Mol. Biol., 126 (2000), pp. 199-211
[Article](#)  [PDF \(1MB\)](#)
- 25 A.M. Schreiber, B. Das, H. Huang, N. Marsh-Armstrong, D.D. Brown
Diverse developmental programs of *Xenopus laevis* metamorphosis are inhibited by a dominant negative thyroid hormone receptor
Proc. Natl. Acad. Sci. USA, 98 (2001), pp. 10739-10744
- 26 Y. Shibota, Y. Kaneko, M. Kuroda, A. Nishikawa
Larval-to-adult conversion of a myogenic system in the frog, *Xenopus laevis*, by larval-type myoblast-specific control of cell division, cell differentiation, and programmed cell death by triiodo-L-thyronine
Differentiation, 66 (2000), pp. 227-238
[Article](#)  [PDF \(1MB\)](#)
- 27 K. Shimizu-Nishikawa, L. Miller
Calcium regulation of epidermal cell differentiation in the frog *Xenopus laevis*
J. Exp. Zool., 260 (1991), pp. 165-169
- 28 K. Shimizu-Nishikawa, L. Miller
Hormonal regulation of adult type keratin gene expression in larval epidermal cells of the frog *Xenopus laevis*
Differentiation, 49 (1992), pp. 77-83
[Article](#)  [PDF \(1MB\)](#)
- 29 K. Shimizu-Nishikawa, I. Tazawa, K. Uchiyama, K. Yoshizato

- 30 Y. Su, S. Damjanovski, Y. Shi, Y.B. Shi
Molecular and cellular basis of tissue remodeling during amphibian metamorphosis
Histol. Histopathol., 14 (1999), pp. 175-183
- 31 Y. Su, Y. Shi, M.A. Stelow, Y.B. Shi
Thyroid hormone induces apoptosis in primary cell cultures of tadpole intestine: Cell type specificity and effects of extracellular matrix
J. Cell Biol., 139 (1997), pp. 1533-1543
- 32 C.H. Thiebaud
A reliable new cell marker in *Xenopus*
Dev. Biol., 98 (1983), pp. 245-249
[Article](#)  [PDF \(3MB\)](#)
- 33 Y. Torrente, J.P. Tremblay, F. Pisati, M. Belicchi, B. Rossi, M. Sironi, F. Fortunato, M. El Fahime, M.G. D'Angelo, N.J. Caron, G. Constantin, D. Paulin, G. Scarlato, N. Bresolin
Intraarterial injection of muscle-derived CD34(+)Sca-1(+) stem cells restores dystrophin in mdx mice
J. Cell Biol., 152 (2001), pp. 335-348
- 34 Y. Yaoita, D.D. Brown
A correlation of thyroid hormone receptor gene expression with amphibian metamorphosis
Genes Dev., 4 (1990), pp. 1917-1924
- 35 Y. Yaoita, K. Nakajima
Induction of apoptosis and CPP32 expression by thyroid hormone in a myoblastic cell line derived from tadpole tail
J. Biol. Chem., 272 (1997), pp. 5122-5127
- 36 Y. Yaoita, Y.B. Shi, D.D. Brown
***Xenopus laevis* alpha and beta thyroid hormone receptors**
Proc. Natl. Acad. Sci. USA, 87 (1990), pp. 7090-7094
- 37 K. Yoshizato
Biochemistry and cell biology of amphibian metamorphosis with a special emphasis on the mechanism of removal of larval organs
Int. Rev. Cytol., 119 (1989), pp. 97-149

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