Developmental Biology

Volume 252, Issue 2, 15 December 2002, Pages 312-323

Regular Article

Neuronal Differentiation from Postmitotic Precursors in the Ciliary Ganglion

Vivian M. Lee [a, b] … Rae Nishi [c, 1]

Show more

https://doi.org/10.1006/dbio.2002.0882

Abstract

In the chick ciliary ganglion, neuronal number is kept constant between St. 29 and St. 34 (E6–E8) despite a large amount of cell death. Here, we characterize the source of neurogenic cells in the ganglion as undifferentiated neural crest-derived cells. At St. 29, neurons and nonneuronal cells in the ciliary ganglion expressed the neural crest markers HNK-1 and $p75^{NTR}$. Over 50% of the cells were neurons at St. 29; of the nonneuronal cells, a small population expressed glial markers, whereas the majority was undifferentiated. When placed in culture, nonneuronal cells acquired immunoreactivity for HuD, suggesting that they had commenced neuronal differentiation. The newly differentiated neurons arose from precursors that did not incorporate bromodeoxyuridine. To test whether these precursors could undergo neural differentiation *in vivo*, purified nonneuronal cells from St. 29 quail ganglia were transplanted into chick embryos at St. 9–14. Subsequently, quail cells expressing neuronal markers were found in the chick ciliary ganglion. The existence of this precursor pool was transient because nonneuronal cells isolated from St. 38 ganglia failed to form neurons. Since all ciliary ganglion neurons are born prior to St. 29, these results demonstrate that there are postmitotic neural crest-derived precursors in the developing ciliary ganglion that can differentiate into neurons in the appropriate environment.

Keywords

ciliary ganglion; parasympathetic; neuronal differentiation; quail; Islet-1; HuD; transplantation; neurogenesis; neural crest

References

REFERENCES

1 D.J. Anderson
Cell and molecular biology of neural crest cell lineage diversification
Curr. Opin. Neurobiol., 3 (1993), pp. 8-13
Article PDF (899KB)

2 D.J. Anderson
MASH genes and the logic of neural crest cell lineage diversification
C. R. Acad. Sci. III, 316 (1993), pp. 1082-1096

3 C.S. Ayer-Le Lievre, N.M. Le Douarin
The early development of cranial sensory ganglia and the potentialities of their component cells studied in quail-chick chimeras
Dev. Biol., 94 (1982), pp. 291-310
Article PDF (47MB)

4 K.F. Barald
Monoclonal antibodies made to chick mesencephalic neural crest cells and to ciliary ganglion neurons identify a common antigen on the neurons and a neural crest subpopulation
J. Neurosci. Res., 21 (1988), pp. 107-118

5 K.F. Barald
Culture conditions affect the cholinergic development of an isolated subpopulation of chick mesencephalic neural crest cells
Dev. Biol., 135 (1989), pp. 349-366
Article PDF (5MB)

6 A.J. Blaschke, K. Staley, J. Chun
Widespread programmed cell death in proliferative and postmitotic regions of the fetal cerebral cortex
Development, 122 (1996), pp. 1165-1174

7 M. Bronner-Fraser, S.E. Fraser
Cell lineage analysis reveals multipotency of some avian neural crest cells
Nature, 335 (1988), pp. 161-164

8 J.N. Coulombe, M. Bronner-Fraser
Cholinergic neurones acquire adrenergic neurotransmitters when transplanted into an embryo
Nature, 324 (1986), pp. 569-572

9 A. D'Amico-Martel
Temporal patterns of neurogenesis in avian cranial sensory and autonomic ganglia
Am. J. Anat., 163 (1982), pp. 351-372

10 S.E. Dryer
Functional development of the parasympathetic neurons of the avian ciliary ganglion: A classic model system for the study of neuronal differentiation and development
Prog. Neurobiol., 43 (1994), p. 281
Article PDF (4MB)

11 E. Dupin
Cell division in the ciliary ganglion of quail embryos in situ and after back-transplantation into the neural crest migration pathways of chick embryos
Dev. Biol., 105 (1984), pp. 288-299
Article PDF (8MB)

12 J. Ericson, S. Thor, T. Edlund, T.M. Jessell, T. Yamada
Early stages of motor neuron differentiation revealed by expression of homeobox gene Islet-1
Science, 256 (1992), pp. 1555-1560

13 A.J. Fischer, T.A. Reh
Muller glia are a potential source of neural regeneration in the postnatal chicken retina
Nat. Neurosci., 4 (2001), pp. 247-252

14 J. Fontaine-Perus, M. Chanconie, N.M. Le Douarin
Developmental potentialities in the nonneuronal population of quail sensory ganglia
Dev. Biol., 128 (1988), pp. 359-375
Article PDF (24MB)

15 E. Frank, J.R. Sanes
Lineage of neurons and glia in chick dorsal root ganglia: Analysis in vivo with a recombinant retrovirus
Development, 111 (1991), pp. 895-908

16 S. Furber, R.W. Oppenheim, D. Prevette
Naturally-occurring neuron death in the ciliary ganglion of the chick embryo following removal of preganglionic input: Evidence for the role of afferents in ganglion cell survival

J. Neurosci., 7 (1987), pp. 1816-1832

17 F. Guillemot, L.C. Lo, J.E. Johnson, A. Auerbach, D.J. Anderson, A.L. Joyner
Mammalian achaete-scute homolog 1 is required for the early development of olfactory and autonomic neurons
Cell, 75 (1993), pp. 463-476
Article PDF (10MB)

18 V. Hamburger, H.L. Hamilton
A series of normal stages in the development of the chick embryo
J. Morphol., 88 (1951), pp. 49-92

19 V. Hamburger, R. Levi-Montalcini
Proliferation, differentiation, and degeneration in the spinal ganglia of the chick embryo under normal and experimental conditions
J. Exp. Zool., 111 (1949), pp. 457-502

20 P.D. Henion, G.K. Blyss, R. Luo, M. An, T.M. Maynard, G.J. Cole, J.A. Weston
Avian transitin expression mirrors glial cell fate restrictions during neural crest development
Dev. Dyn., 218 (2000), pp. 150-159

21 J.G. Heuer, S. Fatemie-Nainie, E.F. Wheeler, M. Bothwell
Structure and developmental expression of the chicken NGF receptor
Dev. Biol., 137 (1990), pp. 287-304
Article PDF (25MB)

22 K. Kuida, T.S. Zheng, S. Na, C.-Y. Kuan, D. Yang, H. Karusayama, P. Rakic, R.A. Flavell
Decreased apoptosis in the brain and premature lethality in CPP32-deficient mice
Nature, 384 (1996), pp. 368-372

23 L. Landmesser, G. Pilar
Synaptic transmission and cell death during normal ganglionic development
J. Physiol., 241 (1974), pp. 737-749

24 N. Le Douarin, F. Dieterlen-Lievre, M.A. Teillet
Quail-chick transplantations
Methods Cell Biol., 51 (1996), pp. 23-59
Article PDF (3MB)

25 N.M. Le Douarin, M.A. Teillet, C. Ziller, J. Smith
Adrenergic differentiation of cells of the cholinergic ciliary and Remak ganglia in avian embryo after in vivo transplantation
Proc. Natl. Acad. Sci. USA, 75 (1978), pp. 2030-2034

26 C.S. Le Lievre, G.G. Schweizer, C.M. Ziller, N.M. Le Douarin
Restrictions of developmental capabilities in neural crest cell derivatives as tested by in vivo transplantation experiments
Dev. Biol., 77 (1980), pp. 362-378
Article PDF (10MB)

27 M.K. Lee, J.B. Tuttle, L.I. Rebhun, D.W. Cleveland, A. Frankfurter
The expression and posttranslational modification of a neuron-specific beta-tubulin isotype during chick embryogenesis
Cell Motil. Cytoskeleton, 17 (1990), pp. 118-132

28 V.M. Lee, M.J. Carden, W.W. Schlaepfer, J.Q. Trojanowski
Monoclonal antibodies distinguish several differentially phosphorylated states of the two largest rat neurofilament subunits (NF-H and NF-M) and demonstrate their existence in the normal nervous system of adult rats
J. Neurosci., 7 (1987), pp. 3474-3488

29 V.M. Lee, G.G. Smiley, R. Nishi
Cell death and neuronal replacement during formation of the avian ciliary ganglion
Dev. Biol., 233 (2001), pp. 437-448
Article PDF (791KB)

30 Q. Ma, Z. Chen, I. del Barco Barrantes, J.L. de la Pompa, D.J. Anderson
Neurogenin1 is essential for the determination of neuronal precursors for proximal cranial sensory ganglia

Neuron, 20 (1998), pp. 469-482
Article PDF (482KB)

31 Q. Ma, C. Fode, F. Guillemot, D.J. Anderson
Neurogenin1 and neurogenin2 control two distinct waves of neurogenesis in developing dorsal root ganglia
Genes Dev., 13 (1999), pp. 1717-1728

32 M.F. Marusich, H.M. Furneaux, P.D. Henion, J.A. Weston
Hu neuronal proteins are expressed in proliferating neurogenic cells
J. Neurobiol., 25 (1994), pp. 143-155

33 M.F. Marusich, J.A. Weston
Identification of early neurogenic cells in the neural crest lineage
Dev. Biol., 149 (1992), pp. 295-306
Article PDF (12MB)

34 S.J. Morrison, P.M. White, C. Zock, D.J. Anderson
Prospective identification, isolation by flow cytometry, and in vivo self-renewal of multipotent mammalian neural crest stem cells
Cell, 96 (1999), pp. 737-749
Article PDF (364KB)

35 R. Nishi
Autonomic and sensory neuron cultures
Methods Cell Biol., 51 (1996), pp. 249-263
Article PDF (977KB)

36 D.M. Noden
The control of avian cephalic neural crest cytodifferentiation. II. Neural tissues
Dev. Biol., 67 (1978), pp. 313-329
Article PDF (14MB)

37 H. Rohrer, A.L. Acheson, J. Thibault, H. Thoenen
Developmental potential of quail dorsal root ganglion cells analyzed in vitro and in vivo
J. Neurosci., 6 (1986), pp. 2616-2624

38 H. Rohrer, S. Henke-Fahle, T. el-Sharkawy, H.D. Lux, H. Thoenen
Progenitor cells from embryonic chick dorsal root ganglia differentiate in vitro to neurons: Biochemical and electrophysiological evidence
EMBO J., 4 (1985), pp. 1709-1714

39 H. Rohrer, I. Sommer
Simultaneous expression of neuronal and glial properties by chick ciliary ganglion cells during development
J. Neurosci., 3 (1983), pp. 1683-1693

40 H. Rohrer, H. Thoenen
Relationship between differentiation and terminal mitosis: Chick sensory and ciliary neurons differentiate after terminal mitosis of precursor cells, whereas sympathetic neurons continue to divide after differentiation
J. Neurosci., 7 (1987), pp. 3739-3748

41 J.W. Sechrist, J. Wolf, M. Bronner-Fraser
Age-dependent neurotransmitter plasticity of ciliary ganglion neurons
Mol. Cell. Neurosci., 12 (1998), pp. 311-323
Article PDF (1MB)

42 M.A. Selleck, M. Bronner-Fraser
Origins of the avian neural crest: the role of neural plate-epidermal interactions
Development, 121 (1995), pp. 525-538

43 I. Sommer, M. Schachner
Monoclonal antibodies (O1 to O4) to oligodendrocyte cell surfaces: An immunocytological study in the central nervous system
Dev. Biol., 83 (1981), pp. 311-327
Article PDF (36MB)

44 Y. Wakamatsu, T.M. Maynard, J.A. Weston
Fate determination of neural crest cells by NOTCH-mediated lateral inhibition and asymmetrical cell division during gangliogenesis
Development, 127 (2000), pp. 2811-2821

45 Y. Wakamatsu, J.A. Weston
Sequential expression and role of Hu RNA-binding proteins during neurogenesis
Development, 124 (1997), pp. 3449-3460

46 G. Weskamp, L.F. Reichardt
Evidence that biological activity of NGF is mediated through a novel subclass of high affinity receptors
Neuron, 6 (1991), pp. 649-663
Article PDF (3MB)

47 A.K. Winseck, J. Caldero, D. Ciutat, D. Prevette, S.A. Scott, G. Wang, J.E. Esquerda, R.W. Oppenheim
In vivo analysis of Schwann cell programmed cell death in the embryonic chick: Regulation by axons and glial growth factor
J. Neurosci., 22 (2002), pp. 4509-4521

1 To whom correspondence should be addressed. Fax: (802) 656-8704. E-mail: rae.nishi@uvm.edu.