A γ/δ T Cell Receptor Heterodimer Induces the Expression of CD4 and CD8 in Thymocytes
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Summary
CD4 and CD8 have been useful surface markers for α/β T cell maturation. In an α/β T cell receptor (TCR) transgenic SCID mice system, it has been shown that α/β TCR alone is sufficient to induce CD4 and CD8 surface expression on thymic T cells. Although the late embryonic thymic γ/δ T cells are predominately single and double positive, it has not been clear if γ/δ TCR has a similar capacity. In this study, we show that when transgenes encoding the earliest embryonic γ/δ TCR are coexpressed with the SCID defect, the γ/δ transgenes promote the appearance of both the CD4−8− and CD4+8+ T cells in the thymus. Furthermore, the expression of CD4 and CD8 does not require continuous surface γ/δ TCR expression. These results indicate that γ/δ TCR alone can promote the appearance of both CD4−8− and CD4+8+ T cells in the thymus, and may suggest a role for γ/δ T cells in initiating normal thymic ontogeny.

Materials and Methods

Animals. C3H/HeJ mice were purchased from The Jackson Laboratory (Bar Harbor, ME) and maintained in our animal facility. CB.17 lcr SCID mice were purchased from the Department of Radiation Biology, Stanford University.

Staining Reagents. The following reagents were used in this study. mAbs: anti-mouse Vβ3 (536)(17), anti-mouse CD3 ε chain (500A2)(18), anti-mouse CD4 (PE-conjugated GK1.5) (Becton Dickinson & Co., Mountain View, CA), anti-mouse CD8 (FITC or biotin-conjugated 53-6.7) (Becton Dickinson & Co.). Others include goat anti-hamster antiserum (Texas Red [TR] conjugated) (Capped Laboratories, Malvern, PA), goat anti-mouse IgG (all phycocyanin [APC] conjugated) (Bio Meda, Foster City, CA), TR-conjugated avidin (Capped Laboratories), APC-conjugated avidin (Bio Meda) normal hamster IgG (Capped Laboratories), goat anti-rat IgG TR conjugated (Caltag, South San Francisco, CA).

TCR Constructs and Transgenic Mice. The functional γ and δ chain constructs represented those isolated from the Thy-1+ dEC clone 717 (19). The γ chain construct contains an EcoRI fragment with the rearranged Vγ3,1Jγ1.1 gene isolated from a phage library derived from the clone 717. The δ chain construct contains a Cla1 fragment with the Vδ1Dδ1 Jδ2 sequence from a cosmids library. The generation of the constructs and transgenic mouse line C3H(T) from C3H/HeJ that expresses the transient γ/δ TCR on T cell surface are described in detail elsewhere (16).

FACS® Analysis. For FACS® analysis (Becton Dickinson & Co., Mountain View, CA), single cell suspensions of thymocytes were
stained as described (17). Detailed combinations of reagents are described in the legend to Fig. 2. Data analysis was performed on 30,000–50,000 cells after proper size gating using the FACS®/DESK Program (Department of Genetics, Stanford University).

SCID Mouse Screening. γ/δ SCID mice were produced by back-crossing (C3H(T) × CB17 Icr SCID)F1, mice with CB17 Icr SCID (20). The mice were screened by ELISA for their serum IgM level using goat anti-mouse IgG (Sigma Chemical Co., St. Louis, MO)-coated plates and alkaline phosphatase-conjugated goat anti-mouse IgM (μ chain specific, Sigma Chemical Co.).

Results and Discussion

Rearranged γ and δ chains genes with TCR coding sequences typical of those found in the earliest fetal thymocytes and adult dendritic epidermal cells (19) (Fig. 1) were co-introduced into the germline of C3H/HeJ mice. Cell surface expression of the transgene was determined by FACS® analysis with a mAb (536) reactive to Vy3 (17). The transgenic γ and δ chains cosegregate in all lineages (data not shown). Two independent lines showing transgene expression in T cells were obtained, but only the experimental results from one is reported in detail (16).

In the adult transgenic thymus, the CD4/CD8 staining pattern is very similar to that of nontransgenic littermates. The transgene-encoded γ chain, and thus, presumably, the heterodimer, are expressed on all double-negative (CD4-8-) cells. 30% of the double-positive (CD4+8+) cells also express only the transgenes (Fig. 2). This is not entirely unexpected, because although normal adult thymic γ/δ T cells are CD4-8+, >35% of the late fetal γ/δ T cells are CD4+8+ (13). One possibility is that these CD4, CD8 antigens expressed on the double-positive γ/δ cells are induced by the endogenous α/β TCR, as it has been shown that α/β TCR alone can induce CD4 and CD8 surface expression on thymic T cells (14). Alternatively, they can be induced by α/β T cells (15). To clarify this issue, we decided to express the γ/δ transgenes on a SCID mouse background. The SCID mouse has defects in Ig and TCR gene assembly, and therefore cannot produce functional Ig or TCR gene products. Because the SCID defect is recessive, we first crossed the transgenic mouse line C3H(T) with SCID, then backcrossed the F1 mice to SCID and analyzed only the progeny that were transgene positive and homozygous for the SCID defect (as assayed by low serum Ig levels).

Introducing this pair of γ/δ TCR genes into SCID mice restores the size of SCID thymus. This is largely, but not exclusively, due to the generation of surface γ/δ-positive cells. The total number of thymocytes in these γ/δ SCID mice is 10–30 times greater than that in the SCID mice. About 75% of the cells express the transgenic γ/δ TCR. There are three major types of thymocytes as defined by surface CD4 CD8 expression (Fig. 3 A); CD4+8+, CD4+8+, and CD4-8-. They represent 50%, 10%, and 40% of the total thymocytes, respectively. Transgene-positive cells can be found in all these compartments (Fig. 3 B). In the γ/δ SCID thymus, no single-positive (CD4+8-, or CD4-8+) cells were present. This is consistent with the supposition that these cells are composed mainly of positively selected α/β T cells. While the number of thymocytes in the γ/δ SCID mouse is similar to that of a normal mouse, the peripheral lymphoid organs remain underdeveloped. This is also consistent with the idea that most of the T cells in these organs are α/β T cells. The lymph node γ/δ T cells in the γ/δ transgenic mice as well as in the γ/δ SCID mice are all CD4-8-. Our results show that a rearranged TCR α or TCR β gene is not a prerequisite for CD4/CD8 expression, and that γ/δ TCR alone can induce the expression of CD4 and CD8 on thymic T cells.

In a normal adult mouse thymus, at least 40% of the CD4+8- cells do not show surface TCR expression (17). However, in either α/β TCR transgenics (21–23) or α/β TCR/SCID mice (14), these TCR-CD4+8- cells are not generally observed. Instead, all the CD4+8- cells in those systems express only the transgenes. In our γ/δ transgenics
and γ/δ SCID mice system, ~60% of the CD4⁺8⁺ thymocytes are TCR⁻, a situation similar to that observed for normal mouse, again reinforcing the idea that the expression of surface CD4 and CD8 does not require persistent surface TCR expression. The fact that not all of the CD4⁺8⁺ cells express the transgenic γ/δ TCR raises the possibility that some of these cells are strictly in the α/β lineage and thus for some reason cannot support γ/δ TCR surface expression.

Recently, Shores et al. (15) transferred normal mouse bone marrow cells to SCID mouse, and observed the appearance of TCR⁻CD4⁺8⁺ and CD4⁻8⁻ cells that are of SCID origin. They postulate that the expression of the CD4, CD8 antigens on these cells is induced by the TCR⁺ bone marrow-derived cells, and speculate that during fetal ontogeny, similar mechanisms may perpetuate the generation of CD4⁺8⁺ α/β lineage cells. While in their experimental system most of the bone marrow-derived cells are α/β TCR⁺, they suggest that during fetal ontogeny, the proposed "inducers" might be CD4⁻8⁻ γ/δ T cells.

In our γ/δ SCID system, we do not know if the cell surface CD4/CD8 expression is induced by the γ/δ transgenes within the cell, or if they were induced by other cells that express surface γ/δ TCR. Nevertheless, our data indicate that the γ/δ TCR derived from d15 fetal thymocytes can promote the entry of immature CD4⁻8⁻ cells into the CD4⁺8⁺ compartment and thus provide useful experimental system for dissecting this process.

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