regulates C3 consumption, thus leading to a C3 deficiency due to its absence) also results in the same type of vulnerability to infection. It has recently been reported that a very rare deficiency in ficolin-3 predisposes affected individuals to bacterial infections. Deficiencies in the alternative pathway (factors D and properdin) are associated with the occurrence of invasive *Neisseria* infections.

Lastly, deficiencies of any complement component involved in the lytic phase (C5, C6, C7, C8, and, to a lesser extent, C9) predispose affected individuals to systemic infection by *Neisseria*. This is explained by the critical role of complement in the lysis of the thick cell wall possessed by this class of bacteria.

Diagnosis of a complement deficiency relies primarily on testing the status of the classic and alternate pathway via functional assays, i.e., the CH50 and AP50 tests, respectively. When either pathway is profoundly impaired, determination of the status of the relevant components in that pathway enables a precise diagnosis. Appropriate vaccinations and daily administration of oral penicillin are efficient means of preventing recurrent infections. It is noteworthy that several complement deficiencies (in the classic pathway and the lytic phase) may also predispose affected individuals to autoimmune diseases (notably systemic lupus erythematosus; Chap. 378).

PRIMARY IMMUNODEFICIENCIES OF THE ADAPTIVE IMMUNE SYSTEM

T LYMPHOCYTE DEFICIENCIES (TABLE 374-1, FIGS. 374-2 AND 374-3)

Given the central role of T lymphocytes in adaptive immune responses (Chap. 372e), PIDs involving T cells generally have severe pathologic consequences; this explains the poor overall prognosis and the need for early diagnosis and the early intervention with appropriate therapy. Several differentiation pathways of T cell effectors have been described, one or all of which may be affected by a given PID (Fig. 374-2). Follicular helper CD4+ T cells in germinal centers are required for T-dependent antibody production, including the generation of Ig class-switched, high-affinity antibodies. CD4+ T_H1 cells provide cytokine-dependent (mostly IFN-γ-dependent) help to macrophages for intracellular killing of various microorganisms, including mycobacteria and *Salmonella*. CD4+ T_H2 cells produce IL-4, IL-5, and IL-13 and thus recruit and activate eosinophils and other cells required to fight helminth infections. CD4+ T_H17 cells produce IL-17 and IL-22 cytokines that recruit neutrophils to the skin and lungs to fight bacterial and fungal infections. Cytotoxic CD8+ T cells can kill infected cells, notably in the context of viral infections. In addition, certain T cell deficiencies predispose affected individuals to *Pneumocystis jiroveci* lung infections early in life and to chronic gut/biliary duct/liver infections by *Cryptosporidium* and related genera later on in life. Lastly, naturally occurring or induced regulatory T cells are essential for controlling inflammation (notably reactivity to commensal bacteria in the gut) and autoimmunity. The role of other T cell subsets with limited T cell receptor (TCR) diversity (such as γδTCR T cells or natural killer T [NKT] cells) in PIDs is less well known; however, these subsets can be defective in certain PIDs, and this finding can sometimes contribute to the diagnosis (e.g., NKT cell deficiency in X-linked proliferative syndrome). T cell deficiencies account for approximately 20% of all cases of PID.

Severe Combined Immunodeficiencies Severe combined immunodeficiencies (SCIDs) constitute a group of rare PIDs characterized by a profound block in T cell development and thus the complete absence of these cells. The developmental block is always the consequence of an intrinsic deficiency. The incidence of SCID is estimated to be 1 in 50,000 live births. Given the severity of the T cell deficiency, clinical consequences occur early in life (usually within 3 to 6 months of birth). The most frequent clinical manifestations are recurrent oral candidiasis, failure to thrive, and protracted diarrhea and/or acute interstitial pneumonitis caused by *Pneumocystis jiroveci* (although the latter can also be observed in the first year of life in children with B cell deficiencies). Severe viral infections or invasive bacterial infections can also occur. Patients may also experience complications related to infections caused by live vaccines (notably bacille Calmette-Guérin [BCG]) that may lead not only to local and regional infection but also to disseminated infection manifested by fever, splenomegaly, and skin and lytic bone lesions. A scaly skin eruption can be observed in a context of maternal T cell engraftment (see below). A diagnosis of SCID can be suspected based on the patient's clinical history and, possibly, a family history of deaths in very young children (suggestive of either X-linked or recessive inheritance). Lymphocytopenia is strongly suggestive of SCID in more than 90% of cases (Table 316-2). The absence of a thymic shadow on a chest x-ray can also be suggestive of SCID. An accurate diagnosis relies on precise determination of the number of circulating T, B, and NK lymphocytes and their subsets. T cell lymphopenia may be masked in some patients by the presence of maternal T cells

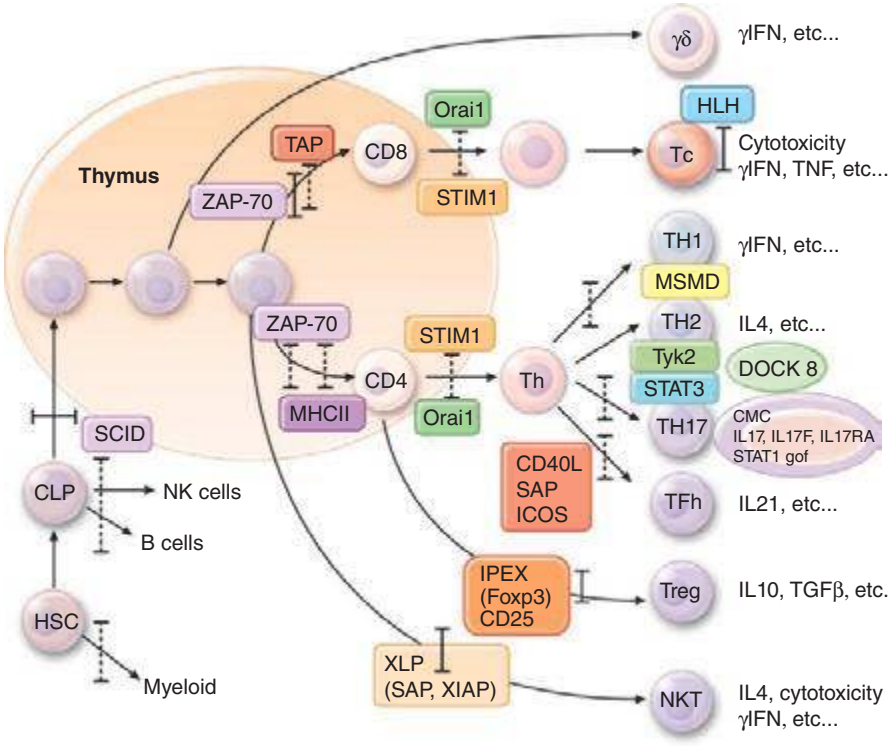

FIGURE 374-2 T cell differentiation, effector pathways, and related primary immunodeficiencies (PIDs). Hematopoietic stem cells (HSCs) differentiate into common lymphoid progenitors (CLPs), which, in turn, give rise to the T cell precursors that migrate to the thymus. The development of CD4+ and CD8+ T cells is shown. Known T cell effector pathways are indicated, i.e., γδ cells, cytotoxic T cells (Tc), T_H1, T_H2, T_H17, TFh (follicular helper) CD4 effector T cells, regulatory T cells (Treg), and natural killer T cells (NKTs); abbreviations for PIDs are contained in boxes. Vertical bars indicate a complete deficiency; broken bars a partial deficiency. SCID, severe combined immunodeficiency; ZAP-70, zeta-associated protein deficiency; MHCII, major histocompatibility complex class II deficiency; TAP, TAP1 and TAP2 deficiencies; Orai1, STIM1 deficiencies; HLH, hematopoietic lymphohistiocytosis; MSMD, Mendelian susceptibility to mycobacterial disease; Tyk2, DOCK8, autosomal recessive form of hyper-IgE syndrome; STAT3, autosomal dominant form of hyper-IgE syndrome; IL17F, IL17RA, STAT1 (gof: gain of function), CMC (chronic mucocutaneous candidiasis), CD40L, ICOS, SAP deficiencies; IPEX, immunodysregulation polyendocrinopathy enteropathy X-linked syndrome; XLP, X-linked proliferative syndromes.