The current classification and diagnosis of diabetes used in the U.S. was developed by the National Diabetes Data Group (NDDG) and published in 1979 (1). The impetus for the classification and diagnosis scheme proposed then holds true today. That is the growth of knowledge regarding the etiology and pathogenesis of diabetes has led many individuals and groups in the diabetes community to express the need for a revision of the nomenclature, diagnostic criteria, and classification of diabetes. As a consequence, it was deemed essential to develop an appropriate, uniform terminology and a functional, working classification of diabetes that reflects the current knowledge about the disease. (1)

It is now considered to be particularly important to move away from a system that appears to base the classification of the disease, in large part, on the type of pharmacological treatment used in its management toward a system based on disease etiology where possible.

An international Expert Committee, working under the sponsorship of the American Diabetes Association, was established in May 1995 to review the scientific literature since 1979 and to decide if changes to the classification and diagnosis of diabetes were warranted. The Committee met on multiple occasions and widely circulated a draft report of their findings and preliminary recommendations to the international diabetes community. Based on the numerous comments and suggestions received, including the opportunity to review unpublished data in detail, the Committee discussed and revised numerous drafts of a manuscript that culminated in this published document.

This report is divided into four sections: definition and description of diabetes, classification of the disease, diagnostic criteria, and testing for diabetes. The aim of this document is to define and describe diabetes as we know it today, present a classification scheme that reflects its etiology and/or pathogenesis, provide guidelines for the diagnosis of the disease, develop recommendations for testing that can help reduce the morbidity and mortality associated with diabetes, and review the diagnosis of gestational diabetes.

DEFINITION AND DESCRIPTION OF DIABETES MELLITUS — Diabetes mellitus is a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. The chronic hyperglycemia of diabetes is associated with long-term damage, dysfunction, and failure of various organs, especially the eyes, kidneys, nerves, heart, and blood vessels.

Several pathogenic processes are involved in the development of diabetes. These range from autoimmune destruction of the B-cells of the pancreas with consequent insulin deficiency to abnormalities that result in resistance to insulin action. The basis of the abnormalities in carbohydrate, fat, and protein metabolism in diabetes is deficient action of insulin on target tissues. Deficient insulin action results from inadequate insulin secretion and/or diminished tissue responses to insulin at one or more points in the complex pathways of hormone action. Impairment of insulin secretion and defects in insulin action frequently coexist in the same patient, and it is often unclear which abnormality, if either alone, is the primary cause of the hyperglycemia.

Symptoms of marked hyperglycemia include polyuria, polydipsia, weight loss, sometimes with polyphagia, and blurred vision. Impairment of growth and susceptibility to certain infections may also accompany chronic hyperglycemia. Acute, life-threatening consequences of diabetes are hyperglycemia with ketoacidosis or the nonketotic hyperosmolar syndrome.

Long-term complications of diabetes include retinopathy with potential loss of vision; nephropathy leading to renal failure; peripheral neuropathy with risk of foot ulcers, amputation, and Charcot joints; and autonomic neuropathy causing gastrointestinal, genitourinary, and cardiovascular symptoms and sexual dysfunction. Glycation of tissue proteins and other macromolecules and excess production of polyol compounds from glucose are among the mechanisms thought to produce tissue damage from chronic hyperglycemia. Patients with diabetes have an increased incidence of atherosclerotic cardiovascular, peripheral vascular, and cerebrovascular disease. Hypertension, abnormalities of lipoprotein metabolism, and periodontal disease are often found in people with diabetes. The emotional and social impact of diabetes and the demands of therapy may cause significant psychosocial dysfunction in patients and their families.

The vast majority of cases of diabetes fall into two broad etiopathogenic categories (discussed in greater detail below). In one category (type 1 diabetes), the cause
is an absolute deficiency of insulin secretion. Individuals at increased risk of developing this type of diabetes can often be identified by serological evidence of an autoimmune pathologic process occurring in the pancreatic islets and by genetic markers. In the other, much more prevalent category (type 2 diabetes), the cause is a combination of resistance to insulin action and an inadequate compensatory insulin secretory response. In the latter category, a degree of hyperglycemia sufficient to cause pathologic and functional changes in various target tissues, but without clinical symptoms, may be present for a long period of time before diabetes is detected. During this asymptomatic period, it is possible to demonstrate an abnormality in carbohydrate metabolism by measurement of plasma glucose in the fasting state or after a challenge with an oral glucose load.

**CLASSIFICATION OF DIABETES MELLITUS AND OTHER CATEGORIES OF GLUCOSE REGULATION** — A major requirement for epidemiological and clinical research and for the clinical management of diabetes is an appropriate system of classification that provides a framework within which to identify and differentiate its various forms and stages. While there have been a number of sets of nomenclature and diagnostic criteria proposed for diabetes, no generally accepted systematic categorization existed until the NDDG classification system was published in 1979 (1). The World Health Organization (WHO) Expert Committee on Diabetes in 1980 and later the WHO Study Group on Diabetes Mellitus endorsed the substantive recommendations of the NDDG (2). These groups recognized two major forms of diabetes, which they termed insulin-dependent diabetes mellitus (IDDM, type 1 diabetes) and non-insulin-dependent diabetes mellitus (NIDDM, type 2 diabetes), but their classification system went on to include evidence that diabetes mellitus was an etiologically and clinically heterogeneous group of disorders that share hyperglycemia in common. The overwhelming evidence in favor of this heterogeneity included the following:

1. There are several distinct disorders, most of them rare, in which glucose intolerance is a feature.
2. There are large differences in the prevalence of the major forms of diabetes among various racial or ethnic groups worldwide.
3. Patients with glucose intolerance present with great phenotypic variation; take for example the differences between thin, ketosis-prone, insulin-dependent diabetes and obese, nonketotic, insulin-resistant diabetes.
4. Evidence from genetic, immunological, and clinical studies shows that in western countries, the forms of diabetes that have their onset primarily in youth are distinct from those that have their onset mainly in adulthood.
5. A type of non-insulin-requiring diabetes in young people, inherited in an autosomal dominant fashion, is clearly different from the classic acute-onset diabetes that typically occurs in children.
6. In tropical countries, several clinical presentations occur, including diabetes associated with fibrocalcinic pancreatitis.

These and other lines of evidence were used to divide diabetes mellitus into five distinct types (IDDM, NIDDM, gestational diabetes mellitus [GDM], malnutrition-related diabetes, and other types). The different clinical presentations and genetic and environmental etiologic factors of the five types permitted discrimination among them. All five types were characterized by either fasting hyperglycemia or elevated levels of plasma glucose during an oral glucose tolerance test (OGTT). In addition, the 1979 classification included the category of impaired glucose tolerance (IGT), in which plasma glucose levels during an OGTT were above normal but below those defined as diabetes.

The NDDG/WHO classification highlighted the heterogeneity of the diabetic syndrome. Such heterogeneity has had important implications not only for treatment of patients with diabetes but also for biomedical research. This previous classification indicated that the disorders grouped together under the term diabetes differ markedly in pathogenesis, natural history, response to therapy, and prevention. In addition, different genetic and environmental factors can result in forms of diabetes that appear phenotypically similar but may have different etiologies.

The classification published in 1979 was based on knowledge of diabetes at that time and represented some compromises among different points of view. It was based on a combination of clinical manifestations or treatment requirements (e.g., insulin-dependent, non-insulin-dependent) and pathogenesis (e.g., malnutrition-related, “other types,” gestational). It was anticipated, however, that as knowledge of diabetes continued to develop, the classification would need revision. When the classification was prepared, a definitive etiology had not been established for any of the diabetes subtypes, except for some of the “other types.” Few susceptibility genes for diabetes had been discovered, and an understanding of the immunological basis for most type 1 diabetes was just beginning.

The current Expert Committee has carefully considered the data and rationale for what was accepted in 1979, along with research findings of the last 18 years, and we are now proposing changes to the NDDG/WHO classification scheme (Table 1). The main features of these changes are as follows:

1. The terms insulin-dependent diabetes mellitus and non-insulin-dependent diabetes mellitus and their acronyms, IDDM and NIDDM, are eliminated. These terms have been confusing and have frequently resulted in classifying the patient based on treatment rather than etiology.
2. The terms type 1 and type 2 diabetes are retained, with arabic numerals being used rather than roman numerals. We recommend adoption of arabic numerals in part because the roman numeral II can easily be confused by the public as the number 11. The class, or form, named type 1 diabetes encompasses the vast majority of cases that are primarily due to pancreatic islet β-cell destruction and that are prone to ketoacidosis. This form includes those cases currently ascribable to an autoimmune process and those for which an etiology is unknown. It does not include those forms of β-cell destruction or failure for which non-autoimmune-specific causes can be assigned (e.g., cystic fibrosis). While most type 1 diabetes is characterized by the presence of islet cell, GAD, IA-2, IA-2B, or insulin autoantibodies that identify the autoimmune process that leads to β-cell destruction, in some subjects, no evidence of autoimmunity is present; these cases are classified as type 1 idiopathic.
3. The class, or form, named type 2 diabetes includes the most prevalent form of diabetes, which results from insulin...
resistance with an insulin secretory defect.

4. A recent international meeting reviewed the evidence for and characteristics of malnutrition-related diabetes (3). While it appears that malnutrition may influence the expression of other types of diabetes, the evidence that diabetes can be directly caused by protein deficiency is not convincing. Therefore, the class malnutrition-related diabetes mellitus has been eliminated. Fibrocalculous pancreatopathy (formerly a subtype of malnutrition-related diabetes) has been reclassified as a disease of the exocrine pancreas.

5. The stage impaired glucose tolerance (IGT) has been retained. The analogous intermediate stage of fasting glucose is named impaired fasting glucose (IFG).

6. Gestational diabetes mellitus (GDM) is retained as defined by the WHO and NDDG, respectively. Selective rather than universal screening for glucose intolerance in pregnancy is now recommended.

7. The degree of hyperglycemia (if any) may change over time, depending on the extent of the underlying disease process (Fig. 1). A disease process may be present but may not have progressed far enough to cause hyperglycemia. The same disease process can cause IFG and/or IGT without fulfilling the criteria for the diagnosis of diabetes. In some individuals with diabetes, adequate glycemic control can be achieved with weight reduction, exercise, and/or oral agents. These individuals therefore do not require insulin. Other individuals who have some residual insulin secretion but require exogenous insulin for adequate glycemic control can survive without it. Individuals with extensive β-cell destruction and therefore no residual insulin secretion require insulin for survival. The severity of the metabolic abnormality can progress, regress, or stay the same. Thus, the degree of hyperglycemia reflects the severity of the underlying metabolic process and its treatment more than the nature of the process itself.

8. Assigning a type of diabetes to an individual often depends on the circumstances present at the time of diagnosis, and many diabetic individuals do not easily fit into a single class. For example:

### Table 1—Etiologic classification of diabetes mellitus

<table>
<thead>
<tr>
<th>Type 1 diabetes*</th>
<th>(β-cell destruction, usually leading to absolute insulin deficiency)</th>
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</thead>
<tbody>
<tr>
<td>A. Immune mediated</td>
<td>B. Idiopathic</td>
</tr>
<tr>
<td>II. Type 2 diabetes*</td>
<td>(may range from predominantly insulin resistance with relative insulin deficiency to a predominantly secretory defect with insulin resistance)</td>
</tr>
<tr>
<td>III. Other specific types</td>
<td>A. Genetic defects of β-cell function</td>
</tr>
<tr>
<td></td>
<td>1. Chromosome 12, HNF-1α (formerly MODY3)</td>
</tr>
<tr>
<td></td>
<td>2. Chromosome 7, glucokinase (formerly MODY2)</td>
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<tr>
<td></td>
<td>3. Chromosome 20, HNF-4α (formerly MODY1)</td>
</tr>
<tr>
<td></td>
<td>4. Mitochondrial DNA</td>
</tr>
<tr>
<td></td>
<td>5. Others</td>
</tr>
<tr>
<td>B. Genetic defects in insulin action</td>
<td>1. Type A insulin resistance</td>
</tr>
<tr>
<td></td>
<td>2. Leprechaunism</td>
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<td></td>
<td>3. Rabson-Mendenhall syndrome</td>
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<td></td>
<td>4. Lipodystrophic diabetes</td>
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<td></td>
<td>5. Others</td>
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<tr>
<td>C. Diseases of the exocrine pancreas</td>
<td>1. Pancreatitis</td>
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<td></td>
<td>2. Trauma/pancreatectomy</td>
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<tr>
<td></td>
<td>3. Neoplasia</td>
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<td></td>
<td>4. Cystic fibrosis</td>
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<td></td>
<td>5. Hemochromatosis</td>
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<td></td>
<td>6. Fibrocalculous pancreatopathy</td>
</tr>
<tr>
<td></td>
<td>7. Others</td>
</tr>
<tr>
<td>D. Endocrinopathies</td>
<td>1. Acromegaly</td>
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<tr>
<td></td>
<td>2. Cushing's syndrome</td>
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<tr>
<td></td>
<td>3. Glucagonoma</td>
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<td></td>
<td>4. Pheochromocytoma</td>
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<td></td>
<td>5. Hyperthyroidism</td>
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<td></td>
<td>6. Somatostatinoma</td>
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<td></td>
<td>7. Aldosteronoma</td>
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<td></td>
<td>8. Others</td>
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<tr>
<td>E. Drug- or chemical-induced</td>
<td>1. Vancor</td>
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<td></td>
<td>2. Pentamidine</td>
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<td></td>
<td>3. Nicotinic acid</td>
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<td></td>
<td>4. Glucocorticoids</td>
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<td></td>
<td>5. Thyroid hormone</td>
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<td></td>
<td>6. Dazoxide</td>
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<td></td>
<td>7. β-adrenergic agonists</td>
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<tr>
<td></td>
<td>8. Thiadizides</td>
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<td></td>
<td>9. Dilantin</td>
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<tr>
<td></td>
<td>10. α-Interferon</td>
</tr>
<tr>
<td></td>
<td>11. Others</td>
</tr>
<tr>
<td>F. Infections</td>
<td>1. Congenital rubella</td>
</tr>
<tr>
<td></td>
<td>2. Cytomegalovirus</td>
</tr>
<tr>
<td></td>
<td>3. Others</td>
</tr>
<tr>
<td></td>
<td>2. Anti-insulin receptor antibodies</td>
</tr>
<tr>
<td></td>
<td>3. Others</td>
</tr>
<tr>
<td>H. Other genetic syndromes sometimes associated with diabetes</td>
<td>1. Down's syndrome</td>
</tr>
<tr>
<td></td>
<td>2. Klinefelter's syndrome</td>
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<tr>
<td></td>
<td>3. Turner's syndrome</td>
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<td></td>
<td>4. Wolfram's syndrome</td>
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<td></td>
<td>5. Friedreich's ataxia</td>
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<td></td>
<td>6. Huntington's chorea</td>
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<td></td>
<td>7. Lawrence Moon Beidel syndrome</td>
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<td></td>
<td>8. Myotonic dystrophy</td>
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<td></td>
<td>9. Porphyria</td>
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<td></td>
<td>10. Prader Willi syndrome</td>
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<tr>
<td></td>
<td>11. Others</td>
</tr>
</tbody>
</table>

*Patients with any form of diabetes may require insulin treatment at some stage of their disease. Such use of insulin does not, of itself, classify the patient.
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<table>
<thead>
<tr>
<th>Types</th>
<th>Stages</th>
<th>Normoglycemia</th>
<th>Hyperglycemia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Normal glucose regulation</td>
<td>Impaired Glucose Tolerance or</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Impaired Fasting Glucose</td>
</tr>
<tr>
<td>Type 1*</td>
<td></td>
<td></td>
<td>Diabetes Mellitus</td>
</tr>
<tr>
<td>Type 2</td>
<td></td>
<td></td>
<td>Not insulin requiring</td>
</tr>
<tr>
<td>Other Specific Types**</td>
<td></td>
<td></td>
<td>Insulin requiring for control</td>
</tr>
<tr>
<td>Gestational Diabetes **</td>
<td></td>
<td></td>
<td>Insulin requiring for survival</td>
</tr>
</tbody>
</table>

Figure 1—Disorders of glycemia: etiologic types and stages. *Even after presenting in ketoacidosis, these patients can briefly return to normoglycemia without requiring continuous therapy (i.e., "honeymoon" remission). **In rare instances, patients in these categories (e.g., Vacor toxicity, type 1 diabetes presenting in pregnancy) may require insulin for survival.

...ple, a person with GDM may continue to be hyperglycemic after delivery and may be determined to have, in fact, type 1 diabetes. Alternatively, a person who acquires diabetes because of large doses of exogenous steroids may become normoglycemic once the glucocorticoids are discontinued, but then may develop diabetes many years later after recurrent episodes of pancreatitis. Another example would be a person treated with thiazides who develops diabetes years later. Because thiazides in themselves seldom cause severe hyperglycemia, such individuals probably have type 2 diabetes that is exacerbated by the drug. Thus, for the clinician and patient, it is less important to label the particular type of diabetes than it is to understand the pathogenesis of the hyperglycemia and to treat it effectively.

Type 1 diabetes (β-cell destruction, usually leading to absolute insulin deficiency)

Immune-mediated diabetes. This form of diabetes, previously encompassed by the term insulin-dependent diabetes, type 1 diabetes, or juvenile-onset diabetes, results from a cellular-mediated autoimmune destruction of the β-cells of the pancreas (4). Markers of the immune destruction of the β-cell include islet cell autoantibodies (ICAs), autoantibodies to insulin (IAAs), autoantibodies to glutamic acid decarboxylase (GAD65), and autoantibodies to the tyrosine phosphatases IA-2 and IA-2β (5-13). One and usually more of these autoantibodies are present in 85-90% of individuals when fasting hyperglycemia is initially detected. Also, the disease has strong HLA associations, with linkage to the DQA and B genes, and it is influenced by the DRB genes (14,15). These HLA-DR/DQ alleles can be either predisposing or protective.

In this form of diabetes, the rate of β-cell destruction is quite variable, being rapid in some individuals (mainly infants and children) and slow in others (mainly adults [16]). Some patients, particularly children and adolescents, may present with ketoacidosis as the first manifestation of the disease. Others have modest fasting hyperglycemia that can rapidly change to severe hyperglycemia and/or ketoacidosis in the presence of infection or other stress. Still others, particularly adults, may retain residual β-cell function sufficient to prevent ketoacidosis for many years. Many such individuals with this form of type 1 diabetes eventually become dependent on insulin for survival and are at risk for ketoacidosis. At this latter stage of the disease, there is little or no insulin secretion, as manifested by low or undetectable levels of plasma C-peptide. Immune-mediated diabetes commonly occurs in childhood and adolescence, but it can occur at any age, even in the 8th and 9th decades of life.

Autoimmune destruction of β-cells has multiple genetic predispositions and is also related to environmental factors that are still poorly defined. Although patients are rarely obese when they present with this type of diabetes, the presence of obesity is not incompatible with the diagnosis. These patients are also prone to other autoimmune disorders such as Graves’ disease, Hashimoto’s thyroiditis, Addison’s disease, vitiligo, and pernicious anemia.

Idiopathic diabetes. Some forms of type 1 diabetes have no known etiologies. Some of these patients have permanent insulinopenia and are prone to ketoacidosis, but have no evidence of autoimmunity. Although only a minority of patients with type 1 diabetes fall into this category, of those who do, most are of African or Asian origin. Individuals with this form of diabetes suffer from episodic ketoacidosis and exhibit varying degrees of insulin deficiency between episodes. This form of diabetes is strongly inherited, lacks immunological evidence for β-cell autoimmunity, and is
Higher blood glucose levels in these diabetic patients to notice any of the classic symptoms is often not severe enough for the patient to recognize. Insulin resistance may improve with weight reduction and/or pharmacotherapy. However, the genetics of this form of diabetes are complex and not clearly defined.

Other specific types of diabetes
Genetic defects of the β-cell. Several forms of diabetes are associated with monoallelic defects in the β-cell function. These forms of diabetes are frequently characterized by onset of mild hyperglycemia at an early age (generally before age 25 years). They were formerly referred to as maturity-onset diabetes of the young (MODY) and are characterized by impaired insulin secretion with minimal or no defects in insulin action (44–46). They are inherited in an autosomal dominant pattern. Abnormalities at three genetic loci on different chromosomes have been identified to date.

The most common form is associated with mutations on chromosome 12 in a hepatic transcription factor referred to as hepatocyte nuclear factor (HNF)-1α (47,48). A second form is associated with mutations in the glucokinase gene on chromosome 7p and results in a defective glucokinase molecule (49,50). Glucokinase converts glucose to glucose-6-phosphate, the metabolism of which, in turn, stimulates insulin secretion by the β-cell. Thus, glucokinase serves as the "glucose sensor" for the β-cell. Because of defects in the glucokinase gene, increased plasma levels of glucose are necessary to elicit normal levels of insulin secretion. A third form is associated with a mutation in the HNF-4α gene on chromosome 20q (51,52). HNF-4α is a transcription factor involved in the regulation of the expression of HNF-1α. The specific genetic defects in a substantial number of other individuals who have a similar clinical presentation are currently unknown.

Point mutations in mitochondrial DNA have been found to be associated with diabetes mellitus and deafness (53–55). The most common mutation occurs at position 3243 in the tRNA leucine gene, leading to an A-to-G transition. An identical lesion occurs in the MELAS syndrome (mitochondrial myopathy, encephalopathy, lactic acidosis, and stroke-like syndrome); however, diabetes is not part of this syndrome, suggesting different phenotypic expressions of this genetic lesion (56).

Genetic abnormalities that result in the inability to convert proinsulin to insulin have been identified in a few families, and such traits are inherited in an autosomal dominant pattern (57,58). The resultant glucose intolerance is mild. Similarly, the production of mutant insulin molecules with resultant impaired receptor binding has also been identified in a few families and is associated with an autosomal inheritance and only mildly impaired or even normal glucose metabolism (59–61).

Genetic defects in insulin action. There are unusual causes of diabetes that result from genetically determined abnormalities of insulin action. The metabolic abnormalities associated with mutations of the insulin receptor may range from hyperinsulinemia and modest hyperglycemia to severe diabetes (62,63). Some individuals with these mutations may have acanthosis nigricans. Women may be virilized and have enlarged, cystic ovaries (64,65). In the past, this syndrome was termed type A insulin resistance (62). Leprechaunism and the Rabson-Mendenhall syndrome are two pediatric syndromes that have mutations in the insulin receptor gene with subsequent alterations in insulin receptor function and extreme insulin resistance (63). The former has characteristic facial features and is usually fatal in infancy, while the latter is associated with abnormalities of teeth and nails and pineal gland hyperplasia.

Alterations in the structure and function of the insulin receptor cannot be demonstrated in patients with insulin-resistant lipoatrophic diabetes. Therefore, it is assumed that the lesion(s) must reside in the postreceptor signal transduction pathways.

Diseases of the exocrine pancreas. Any process that diffusely injures the pancreas can cause diabetes. Acquired processes include pancreatitis, trauma, infection, pancreatectomy, and pancreatic carcinoma (66–68). With the exception of cancer, damage to the pancreas must be extensive for diabetes to occur. However, adenocarcinomas that involve only a small portion of the pancreas have been associated with diabetes. This implies a mechanism other than simple reduction in β-cell mass. If extensive enough, cystic fibrosis and hemochromatosis will also damage β-cells and impair

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insulin secretion (69,70). Fibrocalkinulcus panaeetopathpy may be accompanied by abdominal pain radiating to the back and pancreatic calcifications on X ray (71). Pancreatic fibrosis and calcium stories in the exocrine ducts have been found at autopsy.

**Endocrinopathies.** Several hormones (e.g., growth hormone, cortisol, glucagon, epi- nephrine) antagonize insulin action. Excess amounts of these hormones (e.g., acromegaly, Cushing's syndrome, glucagon- oma, pheochromocytoma) can cause dia- betes (72–75). This generally occurs in individuals with preexisting defects in insulin secretion, and hyperglycemia typically resolves when the hormone excess is removed.

Somatostatinoma- and aldosteronoma- induced hypokalemia can cause diabetes, at least in part, by inhibiting insulin secretion (75,76). Hyperglycemia generally resolves after successful removal of the tumor.

**Drug- or chemical-induced diabetes.** Many drugs can impair insulin secretion. These drugs may not cause diabetes by themselves, but they may precipitate diabetes in individuals with insulin resistance (77,78). In such cases, the classification is unclear because the sequence or relative importance of β-cell dysfunction and insulin resistance is unknown. Certain toxins such as Vacor (a rat poison) and intravenous pentamidine can permanently destroy pancreatic β-cells (79–82). Such drug reactions fortunately are rare. There are also many drugs and hormones that can impair insulin action. Examples include nicotinic acid and glucocorticoids (77,78). Patients receiving α-interferon have been reported to develop diabetes associated with islet cell antibodies and, in certain instances, severe insulin deficiency (83,84). The list shown in Table 1 is not all-inclusive, but reflects the more commonly recognized drug-, hormone-, or toxin-induced forms of diabetes.

**Infections.** Certain viruses have been associated with β-cell destruction. Diabetes occurs in patients with congenital rubella (85), although most of these patients have HLA and immune markers characteristic of type 1 diabetes. In addition, coxsackievirus B, cytomegalovirus, adenovirus, and mumps have been implicated in inducing certain cases of the disease (86–88).

**Uncommon forms of immune-mediated diabetes.** In this category, there are two known conditions, and others are likely to occur. The suff-man syndrome is an autoimmune disorder of the central ner-
Impaired glucose tolerance (IGT) and impaired fasting glucose (IFG)

The terms IGT and IFG refer to a metabolic stage intermediate between normal glucose homeostasis and diabetes. This stage includes individuals who have IGT and individuals with fasting glucose levels \( \geq 110 \text{ mg/dl} \) but \( < 126 \text{ mg/dl} \) (IFG). The term IFG was coined by Charles et al. (115) to refer to a fasting plasma glucose (FPG) level \( \geq 110 \text{ mg/dl} \) (6.1 mmol/l) but \( < 140 \text{ mg/dl} \) (7.8 mmol/l). We are using a similar definition, but with the upper end lowered to correspond to the new diagnostic criteria for diabetes. A fasting glucose concentration of 110 mg/dl has been chosen as the upper limit of "normal." Although it is recognized that this choice is somewhat arbitrary, it is near the level above which acute phase insulin secretion is lost in response to intravenous administration of glucose (116) and is associated with a progressively greater risk of developing micro- and macrovascular complications (117–121).

Note that many individuals with IGT are euglycemic in their daily lives (122) and may have normal or near normal glycated hemoglobin levels (123). Individuals with IGT often manifest hyperglycemia only when challenged with the oral glucose load used in the standardized OGTT.

In the absence of pregnancy, IFG and IGT are not clinical entities in their own right but rather risk factors for future diabetes and cardiovascular disease (117). They can be observed as intermediate stages in any of the disease processes listed in Table 1. IFG and IGT are associated with the insulin resistance syndrome (also known as syndrome X or the metabolic syndrome), which consists of insulin resistance, compensatory hyperinsulinemia to maintain glucose homeostasis, obesity (especially abdominal or visceral obesity), dyslipidemia of the high-triglyceride and/or low-HDL type, and hypertension (124). Insulin resistance is directly involved in the pathogenesis of type 2 diabetes. IFG and IGT appear as risk factors for this type of diabetes at least in part because of their correlation with insulin resistance. In contrast, the explanation for why IFG and IGT are also risk factors for cardiovascular disease is less clear. The insulin resistance syndrome includes well-recognized cardiovascular risk factors such as low HDL levels and hypertension. In addition, it includes hypertriglyceridemia, which is highly correlated with small dense LDL and increased plasminogen activator inhibitor-1 (PAI-1) levels. The former is thought to have enhanced atherogenicity, perhaps as a result of its greater vulnerability to oxidation than normal LDL. PAI-1 is a cardiovascular risk factor probably because it inhibits fibrinolysis. Thus, the insulin resistance syndrome contains many features that increase cardiovascular risk. IFG and IGT may not in themselves be directly involved in the pathogenesis of cardiovascular disease, but rather may serve as statistical risk factors by association because they correlate with those elements of the insulin resistance syndrome that are cardiovascular risk factors.

### Diagnostic Criteria for Diabetes Mellitus

The new criteria

The diagnostic criteria for diabetes mellitus have been modified from those previously recommended by the NDDG (1) or WHO (2). The revised criteria for the diagnosis of diabetes are shown in Table 3. Three ways to diagnose diabetes are possible, and each must be confirmed, on a subsequent day, by any one of the three methods given in Table 3. For example, one instance of symptoms with casual plasma glucose \( \geq 200 \text{ mg/dl} \), confirmed on a subsequent day by 1) FPG \( \geq 126 \text{ mg/dl} \), 2) an OGTT with the 2-h postload value \( \geq 200 \text{ mg/dl} \), or 3) symptoms with a casual plasma glucose \( \geq 200 \text{ mg/dl} \), warrants the diagnosis of diabetes.

For epidemiological studies, estimates of diabetes prevalence and incidence should be based on an FPG \( \geq 126 \text{ mg/dl} \). This recommendation is made in the interest of standardization and also to facilitate field work, particularly where the OGTT may be difficult to perform and where the cost and demands on participants' time may be excessive. This approach will lead to slightly lower estimates of prevalence than would be obtained from the combined use of the FPG and OGTT (Table 4).

The Expert Committee recognizes an intermediate group of subjects whose glucose levels, although not meeting criteria for diabetes, are nevertheless too high to be considered altogether normal. This group, IFG, is defined as having FPG levels \( \geq 110 \text{ mg/dl} \) but \( < 126 \text{ mg/dl} \) or 2-h values in the OGTT of \( \geq 140 \text{ mg/dl} \) but \( < 200 \text{ mg/dl} \). Thus, the categories of FPG values are as follows:

- FPG \( < 110 \text{ mg/dl} \) = normal fasting glucose;
- FPG \( \geq 110 \text{ mg/dl} \) but \( < 126 \text{ mg/dl} \) = IFG;

### Table 2—Screening and diagnosis scheme for GDM

<table>
<thead>
<tr>
<th>Plasma glucose</th>
<th>50-g screening test</th>
<th>100-g diagnostic test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fasting</td>
<td></td>
<td>105 mg/dl</td>
</tr>
<tr>
<td>1-h</td>
<td>140 mg/dl</td>
<td>190 mg/dl</td>
</tr>
<tr>
<td>2-h</td>
<td></td>
<td>165 mg/dl</td>
</tr>
<tr>
<td>3-h</td>
<td></td>
<td>145 mg/dl</td>
</tr>
</tbody>
</table>

Screening for GDM may not be necessary in pregnant women who meet all of the following criteria: <25 years of age, normal body weight, no first-degree relative with diabetes, and not Hispanic, Native American, Asian-, or African-American. The 100-g diagnostic test is performed on patients who have a positive screening test. The diagnosis of GDM requires any two of the four plasma glucose values obtained during the test to meet or exceed the values shown above.
Criteria for the diagnosis of diabetes mellitus

Table 3—Criteria for the diagnosis of diabetes mellitus

1. Symptoms of diabetes plus casual plasma glucose concentration ≥200 mg/dl (11.1 mmol/l). Casual symptoms of diabetes include polyuria, polydipsia, and unexplained weight loss.

2. FPG ≥126 mg/dl (7.0 mmol/l). Fasting is defined as no caloric intake for at least 8 h.

3. 2hPG ≥200 mg/dl during an OGTT. The test should be performed as described by WHO (2), using a glucose load containing the equivalent of 75-g anhydrous glucose dissolved in water.

In the absence of unequivocal hyperglycemia with acute metabolic decompensation, these criteria should be confirmed by repeat testing on a different day. The third measure (OGTT) is not recommended for routine clinical use.

- FPG ≥126 mg/dl = provisional diagnosis of diabetes (the diagnosis must be confirmed, as described above).

The corresponding categories when the OGTT is used are the following:

- 2-h postload glucose (2hPG) <140 mg/dl = normal glucose tolerance;
- 2hPG ≥140 and <200 mg/dl = IGT;
- 2hPG ≥200 mg/dl = provisional diagnosis of diabetes (the diagnosis must be confirmed, as described above).

Since the 2-h OGTT cutoff of 140 mg/dl will identify more people as having impaired glucose homeostasis than will the fasting cutoff of 110 mg/dl, it is essential that investigators always report which test was used.

Rationale for the revised criteria for diagnosing diabetes

The revised criteria are still based on measures of hyperglycemia. Whereas many different diagnostic schemes have been used, all have been based on some measurement of blood or urine glucose, as reviewed by McCance et al. (125). The metabolic defects underlying hyperglycemia, such as islet cell autoimmunity or insulin resistance, should be referred to independently from the diagnosis of diabetes, i.e., in the classification of the disease. Determining the optimal diagnostic level of hyperglycemia depends on a balance between the medical, social, and economic costs of making a diagnosis in someone who is not truly at substantial risk of the adverse effects of diabetes and those of failing to diagnose someone who is (126). Unfortunately, not all these data are available, so we relied primarily on medical data.

Plasma glucose concentrations are distributed over a continuum, but there is an approximate threshold separating those subjects who are at substantially increased risk for some adverse outcomes caused by diabetes (i.e., microvascular complications) from those who are not. Based on part in estimates of the thresholds for microvascular disease, the previous WHO criteria defined diabetes by FPG ≥140 mg/dl, 2hPG ≥200 mg/dl in the OGTT, or both. These criteria effectively defined diabetes by the 2hPG alone because the fasting and 2-h cutpoint values are not equivalent. Almost all individuals with FPG ≥140 mg/dl have 2hPG ≥200 mg/dl if given an OGTT, whereas only about one-fourth of those with 2hPG ≥200 mg/dl and without previously known diabetes have FPG ≥140 mg/dl (127). Thus, the cutpoint of FPG ≥140 mg/dl defined a greater degree of hyperglycemia than did the cutpoint of 2hPG ≥200 mg/dl. It is the consensus of the Expert Committee that this discrepancy is unwarranted and that the cutpoint values for both tests should reflect a similar degree of hyperglycemia and risk of adverse outcomes.

Under the previous WHO and the NDDG criteria, the diagnosis of diabetes is largely a function of which test is performed. Many individuals who would have 2hPG ≥200 mg/dl in an OGTT are not tested with an OGTT because they lack symptoms or because they have an FPG <140 mg/dl. Thus, if it is desired that all people with diabetes be diagnosed and the previous criteria are followed, OGTTs must be performed periodically in everyone. However, in ordinary practice, not only is the OGTT performed infrequently, but it is usually not used even to confirm suspected cases (128). In summary, the diagnostic criteria are now revised to 1) avoid the discrepancy between the FPG and 2hPG cutpoint values and 2) facilitate and encourage the use of a simpler and equally accurate test—fasting plasma glucose—for diagnosing diabetes.

The cutpoint for the 2hPG has been justified largely because at approximately that point the prevalence of the microvascular complications considered specific for diabetes (i.e., retinopathy and nephropathy) increases dramatically. This property of the 2hPG has been compared with the FPG in population studies of the Pima Indians in the U.S., among Egyptians, and in the Third National Health and Nutrition Examination Survey (NHANES III) in the U.S. In other studies, the relationships between glycaemia and macrovascular disease have also been examined.

The relationships of FPG and 2hPG to the development of retinopathy were evaluated in Pima Indians over a wide range of plasma glucose cutpoints (Fig. 2A) (129). Both variables were similarly associated with retinopathy, indicating that by this criterion, each could work equally well for diagnosing diabetes. The authors concluded that both measures were equivalent.

Table 4—Estimated prevalence of diabetes in the U.S. in individuals 40–74 years old using data from the NHANES III

<table>
<thead>
<tr>
<th>Diabetes diagnostic criteria</th>
<th>Prevalence (%) of diabetes by glucose criteria without a medical history of diabetes*</th>
<th>Total diabetes prevalence (%)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical history of diabetes</td>
<td>—</td>
<td>7.92</td>
</tr>
<tr>
<td>WHO (2) criteria for diabetes: FPG ≥140 mg/dl (7.8 mmol/l) or 2hPG ≥200 mg/dl (11.1 mmol/l)</td>
<td>6.34</td>
<td>14.26</td>
</tr>
<tr>
<td>FPG ≥126 mg/dl (7.0 mmol/l)</td>
<td>4.35</td>
<td>12.27</td>
</tr>
</tbody>
</table>

Data are from K. Flegal, National Center for Health Statistics, personal communication. *Diabetes prevalence (by glucose criteria) in those without a medical history of diabetes × (100% — prevalence of diabetes by medical history). †First column of data plus 7.92.

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in terms of the properties previously used to justify diagnostic criteria.

These findings were confirmed in a similar study in Egypt, in which the FPG and 2hPG were each strongly and equally associated with retinopathy (Fig. 2B) (130). For both the FPG and the 2hPG, the prevalence of retinopathy was markedly higher above the point of intersection of the two components of the bimodal frequency distribution (FPG = 129 mg/dl and 2hPG = 207 mg/dl).

In the NHANES III, 2,821 individuals aged 40–74 years received an OGTT, a measurement of HbA1c, and an assessment of retinopathy by fundus photography (K. Flegal, personal communication). Figure 2C shows that all three measures of glycemia (FPG, 2hPG, and HbA1c) are strongly associated with retinopathy, which is similar to the relationships found in the Pima Indians (129) and Egyptians (130), although the relationship was strongest for 2hPG. As in other studies, the prevalence rose dramatically in the highest decile of each variable, corresponding to FPG ≥120 mg/dl, 2hPG ≥195 mg/dl, and HbA1c ≥6.2%. As in the Pima Indian (129) and Egyptian (130) studies, estimates of these "thresholds" for retinopathy are somewhat imprecise. More precision cannot easily be obtained by using narrower glycemic intervals (e.g., 20 instead of the 10 shown in Fig. 2) because of the limited numbers of cases of retinopathy in each sample (32 cases in the Pima study, 146 in the Egyptian study, and 111 in NHANES III). There are no absolute thresholds because some retinopathy occurred at all glucose levels, presumably because of measurement or disease variability and because of nondiabetic causes of retinopathy.

The associations between FPG and 2hPG and macrovascular disease have been examined in adults without known diabetes (131). The 2hPG was somewhat more closely associated with major coronary heart disease, but there was no significant difference in the association of the FPG or the 2hPG with other indexes of macrovascular disease. Similarly, the relationship between glycemia and peripheral arterial disease was studied in 50- to 74-year-old Caucasians (132). The prevalence of arterial disease was strongly related to the FPG and 2hPG. The associations appeared to be of the same strength for both variables.

In a recent analysis of the Paris Prospective Study, the incidence of fatal coronary heart disease was related to both FPG and 2hPG determined at a baseline examination

Figure 2—Prevalence of retinopathy by deciles of the distribution of FPG, 2hPG, and HbA1c in Pima Indians (A) described in McCance et al. (129), Egyptians (B) described in Engelgau et al. (130), and in 40- to 74-year-old participants in NHANES III (C) (K. Flegal, National Center for Health Statistics, personal communication). The x-axis labels indicate the lower limit of each decile group. Note that these deciles and the prevalence rates of retinopathy differ considerably among the studies, especially the Egyptian study, in which diabetic subjects were oversampled. Retinopathy was ascertained by different methods in each study; therefore, the absolute prevalence rates are not comparable between studies, but their relationships with FPG, 2hPG, and HbA1c are very similar within each population.
Table 5—FPG cutoffs equivalent to the WHO 2-h plasma glucose criterion of 200 mg/dl

<table>
<thead>
<tr>
<th>Study and reference</th>
<th>Method</th>
<th>Fasting plasma glucose*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pima Indians (129)</td>
<td>ROC curves†</td>
<td>123 mg/dl (6.8 mmol/l)</td>
</tr>
<tr>
<td>Pima Indians (129)</td>
<td>Equal prevalence‡</td>
<td>120 mg/dl (6.7 mmol/l)</td>
</tr>
<tr>
<td>Several Pacific populations (134)</td>
<td>Equal prevalence‡</td>
<td>126 mg/dl (7.0 mmol/l)</td>
</tr>
<tr>
<td>NHANES III§</td>
<td>Equal prevalence‡</td>
<td>121 mg/dl (6.7 mmol/l)</td>
</tr>
</tbody>
</table>

*The results for the receiver operating characteristics (ROC) curve analysis of the Pima Indian data and those from the Pacific populations appear in the cited publications (in millimoles per liter). The other results have not been published. †Equivalent to the WHO criterion of 2hPG ≥200 mg/dl in sensitivity and specificity for retinopathy from analysis of ROC curves. ‡The method is described by Finch et al. (134). §NHANES III subjects ages 40–74 years, excluding users of insulin and oral hypoglycemic agents, weighted according to sampling plan (K. Flegal, National Center for Health Statistics, personal communication).

(118). Incidence rates were markedly increased at FPG ≥6.9 mmol/l (125 mg/dl) or 2hPG ≥7.8 mmol/l (140 mg/dl). Similarly, the incidence of coronary artery disease and the all-cause mortality rates were predicted by the FPG in the Baltimore Longitudinal Study of Aging (R. Andres, C. Coleman, D. Elahi, J. Fleg, D.C. Muller, J.D. Sorkin, J.D. Tobin, personal communication). The incidence rates of both these outcomes increased markedly and almost linearly above FPG levels in the range of 110–120 mg/dl. In conclusion, both the FPG and 2hPG provide important information regarding risk of both micro- and macrovascular disease, and the approximate thresholds for increased risk correspond with those for retinopathy and with the revised diagnostic criteria.

Reproducibility is another important property of a diagnostic test, a property for which the FPG appears to be preferable. When OGTTs were repeated in adults during a 2- to 6-week interval, the intra-individual coefficients of variation were 6.4% for the FPG and 16.7% for the 2hPG (133).

It is important to review the rationale for retaining the diagnostic cutoff of 200 mg/dl for the 2hPG. This cutoff was originally adopted for three reasons (1,2). First, 200 mg/dl has been found to approximate the cutoff separating the two components of the bimodal distribution of 2hPG. Second, in several studies, the prevalence of microvascular disease sharply increased above 2hPG levels of ~200 mg/dl. Third, an enormous body of clinical and epidemiological data has been collected based on the 2hPG cutoff of 200 mg/dl. Thus, this value has been retained for the diagnosis of diabetes because it would be very disruptive, and add little benefit, to alter the well-accepted 2hPG diagnostic level of ≥200 mg/dl.

Changing the diagnostic cutoff for the FPG to 126 mg/dl is based on the belief that the cutoffs for the FPG and 2hPG should diagnose similar conditions, given the equivalence of the FPG and the 2hPG in their associations with vascular complications and their discrimination between two components of a bimodal frequency distribution (129,130). McCance et al. (129) computed the FPG level equivalent (in sensitivity and specificity for retinopathy) to the 1985 WHO criterion of the 2hPG ≥200 mg/dl and found it to be an FPG of ≥123 mg/dl (Table 5). Finch et al. (134) approached the problem in each of 13 Pacific populations surveyed with OGTTs by determining the value in the FPG that, when used alone as a diagnostic criterion, gave the same prevalence of diabetes as did 2hPG ≥200 mg/dl. The summary estimate from all these populations was a cutoff of 126 mg/dl. The same method was applied to data derived from the Pima Indians and resulted in an FPG cutoff of 120 mg/dl. In NHANES III, the corresponding cutoff was 121 mg/dl (Table 5). These values and the 2hPG cutoff of 200 mg/dl are also quite similar to the values of FPG 129 mg/dl and 2hPG 207 mg/dl that separated the components of the bimodal frequency distributions and identified individuals with a high prevalence of retinopathy among Egyptians (130). Because the standard errors of these estimates are not known, the small differences in the estimates shown in Table 5 may be consistent with sampling variability.

We chose a cutoff at the upper end of these estimates (FPG ≥126 mg/dl, 7.0 mmol/l). This value is slightly higher than most of the estimated cutoffs that would give the same prevalence of diabetes as the criterion of 2hPG ≥200 mg/dl. That is, slightly fewer people will be diagnosed with diabetes if the new FPG criterion is used alone than if either the FPG or the OGTT is used and interpreted by the previous WHO and NDDGS criteria (Table 4).

As noted above, although the OGTT is an acceptable diagnostic test and has been an invaluable tool in research, it is not recommended for routine use. Because of its inconvenience to patients and the perception by many physicians that it is unnecessary, the OGTT is already not widely used for diagnosing diabetes. In addition, it is more costly and time-consuming than the FPG, and the repeat test reproducibility of the 2hPG is worse than that of the FPG (133). If the OGTT is used, either for clinical or research purposes, the test procedure methods recommended by the WHO (2) and the diagnostic criteria in Table 3 should be employed.

HbA₁c measurement is not currently recommended for diagnosis of diabetes, although some studies have shown that the frequency distributions for HbA₁c have characteristics similar to those of the FPG and the 2hPG. Moreover, these studies have defined an HbA₁c level above which the likelihood of having or developing macro- or microvascular disease rises sharply (Fig. 2) (129–132). Furthermore, HbA₁c and FPG (in type 2 diabetes) have become the measurements of choice in monitoring the treatment of diabetes, and decisions on when and how to implement therapy are often made on the basis of HbA₁c. These observations have led some to recommend HbA₁c measurement as a diagnostic test (126,135).

On the other hand, there are many different methods for the measurement of HbA₁c, and other glycosylated proteins, and nationwide standardization of the HbA₁c test has just begun (136). Studies of the utility of the test compared with the FPG and 2hPG have used different assays, thereby making it difficult to assign an appropriate cutoff. Also, the FPG, 2hPG, and HbA₁c tests are imperfectly correlated. In most clinical laboratories, a "normal" HbA₁c is usually based on a statistical sampling of healthy, presumably non-diabetic individuals. In conclusion, HbA₁c remains a valuable tool for monitoring glycemia, but it is not currently recommended for the diagnosis of diabetes.

The revised criteria are for diagnosis and are not treatment criteria or goals of therapy. No change is made in the American Diabetes Association's recommendations of FPG <120 mg/dl and HbA₁c <7%
as treatment goals (137). The new diagnostic cutpoint (FPG ≥126 mg/dl) is based on the observation that this degree of hyperglycemia usually reflects a serious metabolic abnormality that has been shown to be associated with serious complications. The treatment of nonpregnant patients with hyperglycemia near the cutpoint should begin with an individualized lifestyle-modification regimen (i.e., meal planning and exercise). Initiation of pharmacological therapy in these patients has not yet been shown to improve prognosis and may lead to an unacceptably high incidence of hypoglycemic reactions with certain drugs (e.g., sulfonylureas, insulin).

The new criteria have implications for estimates of the prevalence of diabetes. Although an FPG ≥126 mg/dl and a 2hPG ≥200 mg/dl have similar predictive value for adverse outcomes, the two tests are not perfectly correlated with each other. A given person may have one glucose value above one cutpoint and another value below the other cutpoint. Thus, simultaneous measurement of both FPG and 2hPG will inevitably lead to some diagnostic discrepancies and dilemmas. Although diagnosing diabetes by either test will result in a similar number of “cases,” different individuals in different hyperglycemic stages may be identified. (This situation would be even more complicated if a third diagnostic test, such as HbA1c, were used.) However, according to the data reviewed above, there is no basis for concluding that the 2hPG is more reliable than the FPG. Thus, the FPG alone should be used for estimating the comparative prevalence of diabetes in different populations.

Table 4 shows the effect of the new diagnostic criteria on the estimated prevalence of diabetes in the U.S. population aged 40–74 years using data from NHANES III. Diagnosing diabetes in those without a medical history of diabetes by using only the FPG test would result in a lower prevalence of diabetes than would using WHO criteria (4.35 vs. 6.34%). The total prevalence of diabetes (including those with a medical history) would be 12.27%, or 14% lower than the prevalence of 14.26% by the WHO criteria. Of note, these prevalence estimates refer to results of testing on one occasion. The prevalence of diabetes confirmed by a second test will be lower regardless of which criteria are used.

Widespread adoption of the new criteria may, however, have a large impact on the number of people actually diagnosed with diabetes. Presently, about half the adults with diabetes in the U.S. are undiagnosed (127), but many might now be diagnosed if the simpler FPG test were always used.

### TESTING FOR DIABETES IN PRESUMABLY HEALTHY INDIVIDUALS

Type 1 diabetes is usually an autoimmune disease, characterized by the presence of a variety of autoantibodies to protein epitopes on the surface of or within the β-cells of the pancreas. The presence of such markers before the development of overt disease can identify patients at risk (138). For example, those with more than one autoantibody (i.e., ICA, IAA, GAD, IA-2) are at high risk (139–141). At this time, however, many reasons preclude the recommendation to test individuals routinely for the presence of any of the immune markers outside of a clinical trials setting. First, cutoff values for some of the assays for immune markers have not been completely established for clinical settings. Second, there is no consensus yet as to what action should be taken when a positive autoantibody test is obtained. Thus, autoantibody testing may identify people at risk of developing type 1 diabetes without offering any proven measures that might prevent or delay the clinical onset of disease. Of note, however, is that there are a number of ongoing well-controlled clinical studies testing various means of preventing type 1 diabetes. These studies conducted in high-risk subjects may one day offer an effective means to prevent type 1 diabetes, in which case screening may become appropriate. Last, because the incidence of type 1 diabetes is low, routine testing of healthy children will identify only the small number (<0.5%) who at that moment may be “prediabetic.” Thus, the cost-effectiveness of such screening is questionable, at least until an effective therapy is available. For the above reasons, the clinical testing of individuals for autoantibodies related to type 1 diabetes, outside of research studies, cannot be recommended at this time. Similarly, antibody testing of high-risk individuals (e.g., siblings of type 1 patients) is also not recommended until the efficacy and safety of therapies to prevent or delay type 1 diabetes have been demonstrated. On the other hand, the autoantibody tests may be of value to identify which newly diagnosed patients have immune-mediated type 1 diabetes in circumstances where it is not obvious, particularly when therapies become available to preserve β-cell mass.

Undiagnosed type 2 diabetes is common in the U.S. As many as 50% of the people with the disease, or about 8 million individuals, are undiagnosed (127). Of concern, there is epidemiological evidence that retinopathy begins to develop at least 7 years before the clinical diagnosis of type 2 diabetes is made (142). Because hyperglycemia in type 2 diabetes causes microvascular disease and may cause or contribute to macrovascular disease, undiagnosed diabetes is a serious condition. Patients with undiagnosed type 2 diabetes are at significantly increased risk for coronary heart disease, stroke, and peripheral vascular disease. In addition, they have a greater likelihood of having dyslipidemia, hypertension, and obesity (143).

Thus, early detection, and consequently early treatment, might well reduce the burden of diabetes-related complications.
den of type 2 diabetes and its complications. However, to increase the cost-effectiveness of testing undiagnosed, otherwise healthy individuals, testing should be considered in high-risk populations. Suggested criteria for testing are given in Table 6. Factors leading to these recommendations include: 1) the steep rise in the incidence of the disease after age 45 years, 2) the negligible likelihood of developing any of the complications of diabetes within a 3-year interval of a negative screening test, and 3) knowledge of the well-documented risk factors for the disease. Although the OGTT and FPG are both suitable tests, in clinical settings, the FPG is strongly recommended because it is easier and faster to perform, more convenient and acceptable to patients, more reproducible, and less expensive.

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