Introduction
It is fitting that a session about placental function is held during a colloquium about pre- and postpartum nutrition and metabolism. The placenta serves as lung, kidney, gut, and liver for the fetus. Of particular importance are biochemical and metabolic inter-relationships of the placenta and fetus that promote their mutual nutrition, growth and development. Understanding these inter-relationships can provide important insight into the nutritional needs and metabolic capacities of the newborn infant, especially those born preterm.

Placental and fetal growth
Placental growth increases over gestation, concomitant with or ahead of fetal growth [1], and failure of placental growth, experimentally or naturally, is directly associated with decreased fetal growth [2]. Despite this strong relationship, increased placental transport and metabolism add markedly to placental function, even when the placenta does not grow. For example, placental excretion of urea, water and salt transfer capacity, and transport of glucose to the fetus in sheep increase with gestation, even when placental size does not change or decreases [3]. Furthermore, placental growth and function are intimately related to placental vascular development [4], and to the production of hormones and growth factors which are important for promoting placental and fetal growth as well as placental nutrient uptake, metabolism, and transport to the fetus.

Prologue: placental–fetal metabolic inter-relationships

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Placental–fetal metabolic inter-relationships

Glucose
The kinetics of placental–fetal glucose exchange depend on a dynamic inter-relationship of several placental and fetal metabolic processes [5]. These include: (i) maternal and fetal plasma glucose concentrations; (ii) uteroplacental glucose metabolism; (iii) the function of the facilitative glucose transporter proteins according to saturation kinetics; (iv) glucose utilization rate in the fetus, which is regulated by developmental increase in insulin secretion and insulin-sensitive tissues. Current important research is directed at how glucose uptake and transfer by the placenta, and glucose uptake and metabolism by fetal tissues, are mediated by glucose transporter proteins. This research is focused also on how the developmental increase and intracellular versus membrane localization of these transporters are regulated, and whether changes in plasma glucose and insulin concentrations alter their expression, localization, and function [6].

Amino acids
Most amino acids are actively taken up from the maternal plasma by transporter proteins in the microvillous membrane and concentrated in the trophoblast cytosol [7]. The relative quantity and activity of the amino transporters in the placenta determine the quantity and relative proportions of the amino acids that get to the fetus [8]. Most of the amino acids are supplied to the fetus in excess of the requirements for nitrogen accre-
tion, providing carbon for oxidation (and gluconeogenesis under certain circumstances) [9]. An excess of amino acids also ensures adequate amino acid and nitrogen supplies for the synthesis of non-essential amino acids, which are important for fetal protein synthesis and regulatory properties of amino acid metabolism. The unique supply of amino acids to the fetus also is regulated by placental metabolism of amino acids taken up from the maternal circulation, by fetal hepatic and peripheral tissue metabolism, and by re-uptake and subsequent metabolism of some of these amino acids by the placenta [10]. In direct relationship to fetal amino acid supply, the fractional rate of fetal protein turnover is in considerable excess of the fractional rate of fetal growth [11], and both are much higher in midgestation than at term. Many examples of fetal growth restriction demonstrate less than normal fetal amino acid uptake rates and plasma concentrations [12], and a current important area of research is to determine how fetal amino acid supply can be manipulated to improve fetal growth and development.

**Lipids**

Fatty acids, as well as mono- and diglycerides, carried in the maternal plasma or released from circulatory lipoproteins by placental lipoprotein lipase can be directly transported to the fetus or re-incorporated into triglycerides in the trophoblast before entry into the fetal circulation [13]. Fetuses of all species require placental transfer of essential fatty acids, principally linoleic and linolenic acid, and their long-chain polyunsaturated derivatives, arachidonic and docosahexaenoic acid [14], to produce structural components of membranes. In those species that readily transport lipids across the placenta, the principal interaction with the fetus is fetal lipogenesis in adipose tissue, as fetal lipid metabolism appears to be limited in its capacity for oxidation of long-chain fatty acids because of a relatively low carnitine concentration [15]. In this role, the human fetus excels, developing as much as 15–18% body-weight as fat by term, in contrast to 10–11% for guinea pigs, 6–7% for rabbits, and only 2–3% for sheep [16].

**Summary**

Placental–fetal metabolic inter-relationships are complex and dynamic. The placenta consumes glucose as well as transporting it to the fetus, and both of these processes are related to the rates of fetal glucose utilization and production. For amino acids and fatty acids, unique placental transport and metabolic processes determine the quality as well as the quantity of these substrates that enter the fetal circulation. In turn, the unique qualitative and quantitative supplies of amino acids and fatty acids provide regulation of diverse developmental metabolic processes, including fetal protein turnover, protein accretion and growth, and lipogenesis. Clearly, placental and fetal metabolic inter-relationships represent vital and unique processes that control and determine many aspects of fetal development.

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An overview of early post-partum nutrition and metabolism

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Introduction

The perinatal period is attended by important modifications in several physiological functions, in particular dramatic changes in nutrition. In utero, the fetus receives a continuous intravenous supply of substrates for growth and oxidative metabolism and it produces large quantities of CO₂ and urea [1]. Immediately after birth, the maternal supply of substrates ceases abruptly, and the newborn has to withstand a brief period of starvation before he/she is fed at intervals with milk which is a high-fat/low-carbohydrate diet. The successful adaptation of neonates to these changes in nutrition and environment require important modifications of glucose and fatty acid metabolism, that are mainly orchestrated by alterations in hormone secretion.

The aim of this report is to overview the metabolic adaptations of glucose and free fatty acid metabolism during the perinatal period. Most of the data on this subject comes from experimental studies performed in animals, especially the rat. The relevance of animal studies in the understanding of fuel homeostasis in the human baby will be discussed.

Nutritional and hormonal changes during the perinatal period

Nutritional changes

During pregnancy, the fetus is continuously supplied through the placenta with a diet rich in carbohydrate and amino acids and poor in fat [1].

In most species free fatty acids (FFA) are poorly transferred across the placenta, and in the few species in which the placenta is permeable to FFA (human, guinea-pig, rabbit), they are stored as triglycerides in the liver and adipose tissue but are poorly oxidized by fetal tissues [2]. Immediately after birth, the newborn has to withstand a brief period of starvation before he/she is fed at intervals with milk. From an energy point of view, milk is a high-fat/low-carbohydrate diet [3]. In the rat, lactose and fat contents in milk represent 3 g/100 g and 10 g/100 g respectively. In human milk, the lactose content is higher and the fat content is lower (7 g/100 g and 4 g/100 g respectively) [3]. Nevertheless, fat represents more than 50% of the energy intake of the neonate of most species [2]. Lactose is the predominant carbohydrate in the milk, and 95% of milk fat is in the form of triglycerides. The nutrient content of milk depends also upon the stage of lactation. Colostrum is characterized by a lower lactose and a higher fat content than the mature milk [2]. The fatty acid composition of milk triglycerides shows marked species differences, depending upon the chain length and the degree of saturation of fatty acid. For example, milk from human, guinea-pig or pig contains a very high proportion of long-chain fatty acids (85–99% of triglycerides), whereas milk from rat or rabbit contains a high proportion of medium-chain fatty acids (30–70% of milk triglycerides) [3]. Moreover, a significant amount of short-chain fatty acids is detectable in the milk triglycerides of ruminants [3].

Hormonal changes

The hormonal changes that occur during the immediate postnatal period have been reviewed recently [2] and will be briefly summarized. A large increase in plasma glucagon occurs in new-