CELEBRATING DIVERSITY IN TWINNING: A COMPREHENSIVE NON-MEDICAL REVIEW OF TWIN TYPES AND THEIR GENETIC ORIGINS

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ABSTRACT

This review examines the complexities of twinning beyond the traditional monozygotic and dizygotic categories, encompassing a range of less conventional types. Through an examination of studies spanning the last three decades, this paper provides a comprehensive synthesis of the non-medical literature concerning the genetic and developmental diversity of twinning. It highlights the unique genetic interrelations and developmental pathways characteristic of rarer forms, such as superfecundation, superfetation, and chimerism. These insights advance the understanding of genetic individuality and offer implications for genetic counselling and the broader field of reproductive sciences. The research employs a descriptive approach to synthesize findings from a broad survey of the literature, crafting a narrative that reveals the intricate genetic and developmental intricacies of twinning. This paper, targeting both academic and wider audiences, underscores the importance of recognizing the diversity within twinning phenomena and its significance in understanding human development and genetics.

Keywords: Chimerism, Developmental Biology, Genetic Counseling, Genetic Diversity.

INTRODUCTION

Twinning, a captivating biological phenomenon, has long been a subject of both scientific inquiry and cultural fascination. While the general populace is often familiar with the basic distinctions of identical and fraternal twins, the full spectrum of twinning is far more intricate and diverse than these common classifications suggest. This paper endeavours to provide a comprehensive review of the various types of twins, delving beyond the well-known monozygotic and dizygotic categories to explore the lesser-known and more enigmatic types such as super fecundated, superfetated, and chimaera twins. By drawing upon a wealth of established research, including seminal works by experts like Segal (1), Langkamp & Girardet (2), and Fierro (3), this review aims to offer readers a thorough and enlightening overview of the multifaceted world of twinning, its genetic underpinnings, and its developmental implications.

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Zygosity

Zygosity indicates the degree of genetic similarities or dissimilarities among different types of twins, triplets, or other higher-order multiples (4). Twin zygosity is determined by DNA or blood group polymorphisms (5). The DNA test determines zygosity by comparing the blood cells of each twin (3). In other cases, the zygosity of multiple births could be determined from their perceived similarity and dissimilarity as reported by their parents (6). hair appearance (e.g., eye colour, hair colour, structure), There are, in fact, several studies in

which zygosity was determined based on answers to validated questionnaires, where the accuracy of zygosity determination was relatively high (4-12). Multiple births are routinely classified by zygosity and described based on how they form (3).

Types of Twinning

There are two primary types of twinning: identical or monozygotic twins "mono = one, zygote= egg" and fraternal or dizygotic twins "di = two, zygote = egg" (1). Both monozygotic and dizygotic twins make up closely 95% of all multiple births (2).

Monozygotic (MZ) Twins (Figure 1)**:**

MZ twins arise when a single egg and sperm meet, and a zygote is formed; that zygote can then spontaneously split into two (or more) fetuses (1), (13), (14). The timing of this splitting determines the number of placentas and the number of chorion and amniotic sacs of the pregnancy; essentially, the later the splitting occurs, the more components will be shared between the MZ twins (10). Consequently, there are three different types of MZ twins; when the zygote splits during the first three days after fertilization, the result is dichorionic–diamniotic MZ twins, each twin has his/her own placenta, chorionic sac, and amniotic sac (dichorionic–diamniotic MZ twins account for about 20-25% of all MZ twins). The second type is monochorionic–diamniotic MZ twins which occur 8 days after fertilization; they share one placenta and one chorionic sac but have their own amniotic sac (monochorionic–diamniotic MZ twins account for about 70-75% of all MZ twins). If the division happens about 15 days after fertilization, the result is monochorionic monoamniotic MZ twins; they share one placenta, one chorionic sac, and one amniotic sac (monochorionic–monoamniotic MZ twins account for only 1-5% of all MZ twins) (10) "See Figure 1". Monozygotic twin fetuses that share one placenta and one amniotic sac may be at risk for Twin-to-Twin Transfusion Syndrome (TTTS), a disease of the placenta that occurs when an unbalanced flow of blood circulates from one twin to the other (15). MZ twins have identical genetic makeup (DNA) (16), so they will always be the same sex and also share very similar physical characteristics (4), (17); their abilities may also be very closely matched (18). Nearly one-third of all twins are monozygotic (19), and the rate of this type of twinning remains relatively constant (2). However, the factors that cause monozygotic twin births remain unknown (3).

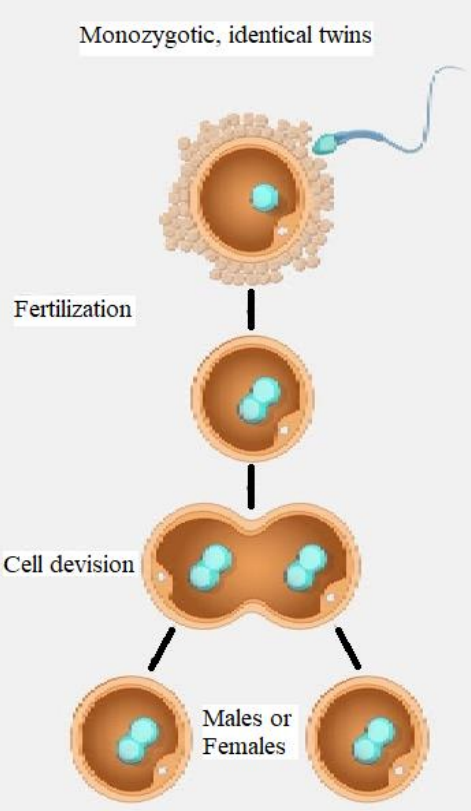

Figure 1: Courtesy National Human Genome Research Institute. (2023). Identical twins are also called monozygotic twins. Retrieved October 22, 2023, from https://www.genome.gov/genetics-glossary/identical-twins

Dizygotic (DZ) Twins (Figure 2)**:**
DZ twins, on the other hand, occur when two different eggs (or more) are fertilized by two separate sperm cells and implant in the uterus during the same menstrual cycle, resulting in two zygotes (1,13,14). Each zygote develops its own placenta, chorion, and amniotic sac; these are termed dichorionic–diamniotic DZ twins (10) "See Figure 2". DZ twins share approximately 50 percent of their DNA, similar to any two siblings born to the same parents at different times (14-16). DZ twins can be of the same gender or of different genders, and they may look alike or completely different (4), (17). They might also have distinctive abilities (18). Generally, two-thirds of all twins are dizygotic (19), and the rate of dizygotic twinning is influenced by factors such as the increased use of infertility treatments like in vitro fertilization (IVF), maternal age over 35, heredity, race, and nutrition (20) Twin studies, in general, assume that monozygotic twins are at an increased risk of stillbirth, infant death, malformations, and cerebral palsy compared with dizygotic twins (6).

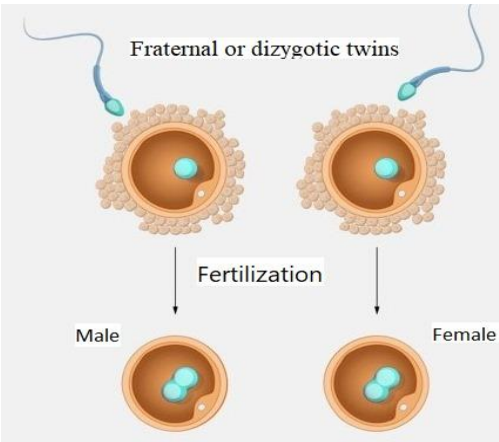

Figure 2: Courtesy National Human Genome Research Institute. (2023). Fraternal twins are also called dizygotic twins. Retrieved October 22, 2023, from https://www.genome.gov/genetics-glossary/Fraternal-Twins.

Super twins
Super twins which include triplets and other higher-order multiples (quadruplets, quintuplets), can be monozygotic, dizygotic, or even a mixture of both types (18). Triplets account for approximately 91% of all higher-order multiples (2). Twins and triplets are often delivered preterm. On average, twins are born at 36 weeks, triplets at 32 weeks, and quadruplets at 29 weeks (20). The majority of children from multiple births are born prematurely, and often, they don't reach a healthy birth weight, increasing their risk of health problems (2). As Hamilton and colleagues (20) noted, " Twins and triplets are also more likely not to survive the first year of life." The mortality rate for infants who are twins is 24%, whereas it's 5.4% for single-birth infants (21).

***Polar Body Twinning*:**
Scientists have suggested another unofficial type of twinning called polar body twinning, or semi-identical twins (19). Polar body twins occur when a single egg splits prior to fertilization. Each half then receives a different sperm, and each develops into a fetus (19). Ultimately, polar body twins share about 75 percent of their DNA. They share 100 percent of their mother's genes and 50 percent from each of their father's sperm (25). These twins can be of the same sex or opposite sex because the father's sperm determines the baby's gender (25). They would be less alike than MZ twins but more alike than DZ twins (3).

***Conjoined Twins*:**
Conjoined twins are always monozygotic twins who are physically connected in utero at certain points on their bodies (22). Conjoined twins occur when the fertilized zygote is delayed in splitting or fails to separate completely (23). The incidence of this type of twinning is very low, reported in only one out of every

50,000 to 100,000 pregnancies (24). The majority of conjoined twins are females, with a ratio of 3:1 (23), for reasons not yet fully understood by science (3).

Mirror Image Twins:

Mirror image twins are a subset of monozygotic twins (19). It's theorized that mirror image twins occur in approximately one quarter of all monozygotic twins due to delayed splitting of the zygote, after the developing fetus has slightly designated right and left sides. If this condition occurs, one twin may be right-handed and the other left-handed. Additionally, they might have many physical features (e.g., moles, hair whorls) on opposite sides of each other (3,19). These twins' risk being conjoined (25).

Superfetated Twins:

Superfetated twins are an unusual type of DZ twins. Superfetation occurs when a woman's body ovulates twice, days or weeks apart (22). In other words, a woman gets pregnant again after the first zygote has already implanted in the womb. The result is twins that are conceived at different times and may be delivered days or weeks apart (1).

Super fecundated Twins:

Super fecundated twins represent another rare type of DZ twins (22). Superfecundation refers to the conception of twins by two different fathers, resulting from multiple acts of sexual intercourse with different men within the same menstrual cycle (1).

Vanishing Twin Syndrome:

A vanishing twin occurs when a twin disappears from the uterus during pregnancy as a result of a miscarriage of one twin. The fetal tissue is absorbed by the other twin, the mother, or the placenta, which lead to the surviving twin having two sets of DNA, known as chimerism (26). According to Landy & Keith (27), vanishing twin syndrome occurs in roughly 30% of twin pregnancies.

Chimera Twins:

Chimera result from the fusion of two fraternal twin embryos and develop into one baby. This phenomenon occurs when one twin fetus dies early in the womb, and the surviving twin absorbs some cells of the vanishing fetus. As a result, the born twin contains a mixture of two types of DNA: its own original cells and the cells from its deceased twin (28).

DISCUSSION

The exploration of twinning presented in this review underscores the remarkable complexity of human reproduction and genetic variance. The phenomenon of twinning extends well beyond the traditional binary of monozygotic and dizygotic twins, encompassing a spectrum of types each with distinct genetic and developmental profiles. The occurrence of superfecundation and superfetation, for instance, challenges our understanding of human gestation and raises questions about the biological mechanisms that allow for such rare events. Similarly, the existence of chimera twins blurs the lines of individual genetic identity, presenting unique medical and ethical considerations.

One of the most striking implications of this diversity in twinning is its impact on the field of genetics and developmental biology. Monozygotic twinning offers a natural control for genetic studies, while the genetic dissimilarities in dizygotic twins can help disentangle the influences of environment and heredity. The study of superfetated and super fecundated twins could further illuminate the intricacies of fertility and embryonic development. However, the study of twinning is not without its challenges.

The rarity of certain twin types, such as polar body twins or superfetated twins, makes gathering a large and statistically significant sample size difficult. Moreover, the diagnosis of zygosity, while improved, still relies on the accuracy of DNA testing, which may not always be accessible or feasible in certain populations or regions.

The potential for future research in this area is vast. Advances in genetic testing could provide deeper insights into the zygosity of twins and the occurrence of genetic anomalies. Longitudinal studies could explore the developmental, psychological, and health trajectories of twins, particularly those with unusual twinning types. Furthermore, the increasing prevalence of assisted reproductive technologies (ART) and their role in twinning rates presents another rich avenue for investigation, especially as it pertains to the ethics and health outcomes associated with multiple births from ART.

CONCLUSION

The multifaceted world of twinning is as complex as it is captivating. Moving beyond the traditional dichotomy of identical and fraternal twins, this review has illuminated a spectrum of twin types, each with its own genetic blueprint and developmental narrative. From the shared DNA of monozygotic twins to the genetic mosaic found in chimeras, twinning provides a unique lens through which we can examine the intricacies of human genetics and embryonic development.

This comprehensive overview has bridged well-established knowledge with recent discoveries, offering a nuanced understanding of twin types such as super fecundated, superfetated, and mirror image twins, among others. These categories not only enrich our knowledge but also challenge our preconceived notions about individuality and genetic determinism.

As we continue to unravel the genetic and environmental factors that contribute to the phenomenon of twinning, our appreciation for its diversity only deepens. The implications of this diversity extend beyond academic curiosity, influencing medical practice, genetic counseling, and our understanding of human development.

In synthesizing the current state of knowledge, this review underscores the importance of continued research in the field of genetics. It is a call to action for embracing the diversity inherent in twinning and for fostering a sense of wonder at the biological processes that make each human being unique. As the field evolves, so too will our insights into the remarkable phenomenon of twinning, promising to reveal even more about the wondrous nature of human life.

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