NATIONAL SENIOR CERTIFICATE EXAMINATION
MAY 2025

LIFE SCIENCES: PAPER II

SOURCE MATERIAL BOOKLET FOR QUESTIONS 1, 2 AND 3

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SECTION A

QUESTION 1

Read the information below. Use this information, as well as your own knowledge, to answer Question 1 in the question paper.

NEW APPROACHES TO MALE CONTRACEPTION

1. Contraceptive justice

The global population exceeds 8,2 billion and grows by 80 million annually, with 41% of pregnancies not planned. Limited access to effective contraception contributes to these high rates of unplanned pregnancies. The development of a male contraceptive pill is essential to addressing inequalities in reproductive responsibilities. Women have access to 13 contraceptive methods, while men are limited to 3 (Table 1.1). This imbalance places a significant financial, health, and emotional burden on women, while also limiting men's reproductive choices. A male pill could promote shared responsibility and improve family planning fairness.

Table 1.1: Comparison of contraception options for men and women

Women ♀	Duration of Action	Men ♂
Diaphragms, Spermicides, Female Condoms, Rhythm	During intercourse	Male Condoms, Withdrawal
Hormonal Control (daily pills, weekly patches, morning-after pill)	Short-acting	Nothing
Hormonal Control (monthly/3-monthly Injectable)	Medium-acting	Nothing
Hormonal Implants, Intrauterine Devices (up to 10 years)	Long acting	Nothing
Tubal Ligation	Permanent	Vasectomy

Women face numerous challenges with existing contraceptives. These methods are often expensive, requiring doctors' visits or prescriptions, and medical aids usually do not cover contraceptive use. Hormonal contraceptives frequently cause side effects, such as mood changes or health risks, leading to nearly 50% of women annually abandoning their hormonal birth control methods.

Men's contraceptive options, while less risky, have significant limitations. Condoms, with a failure rate of 16%, are prone to user error or breakage. Vasectomy, though highly effective (failure rate under 1%), is largely irreversible, making it unsuitable for men seeking to reproduce in the future. Withdrawal, used by 3–5% of couples, is highly unreliable, with failure rates of 20–30%. The lack of effective and reversible male contraceptives forces men to depend on women's contraceptive use, continuing injustices in reproductive health responsibilities.

[Adapted from: Campo-Engelstein L 2012. Contraceptive justice: Why we need a male pill. *AMA Journal of Ethics* 14(2): 146–151]
[Table 1.1: <http://malecontraceptive.org/uploads>]

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2. Challenges with male contraceptives – Male reproductive physiology

Challenges with male contraceptives: A big challenge with male contraceptives is the need to reduce sperm count almost completely to prevent pregnancy. We currently have a very limited understanding of how sperm production actually works. A reduction in sperm count can cause unwanted side effects, like testes shrinkage. A decrease in the number of germinal cells can also negatively impact testes size and function and disrupts the hormonal feedback loop between the pituitary and the testes.

How sperm production works: Sperm production occurs in the testes with the assistance of two types of cells, under the influence of testosterone (Figure 1.1). Sertoli cells form the walls of the seminiferous tubules and supply nutrients to developing germinal cells (Figures 1.1 and 1.2). Leydig cells, found in the interstitial tissue between seminiferous tubules (Figures 1.1 and 1.2), produce testosterone, which acts on Sertoli cells and germinal cells to stimulate and maintain sperm production.

Figure 1.1: Hormonal control of human sperm production

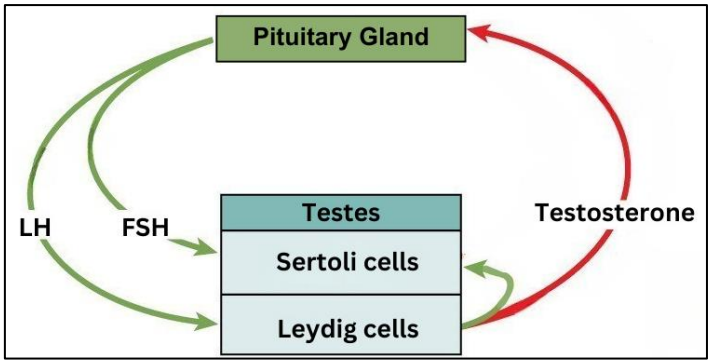
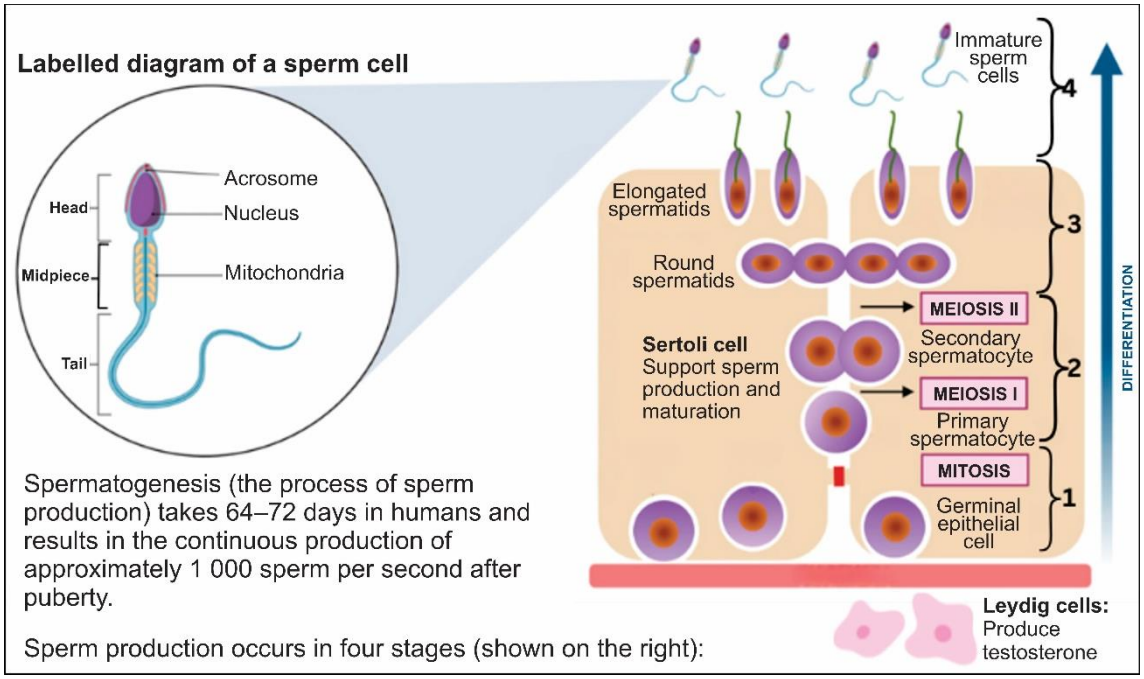


Figure 1.2: Stages of human sperm production

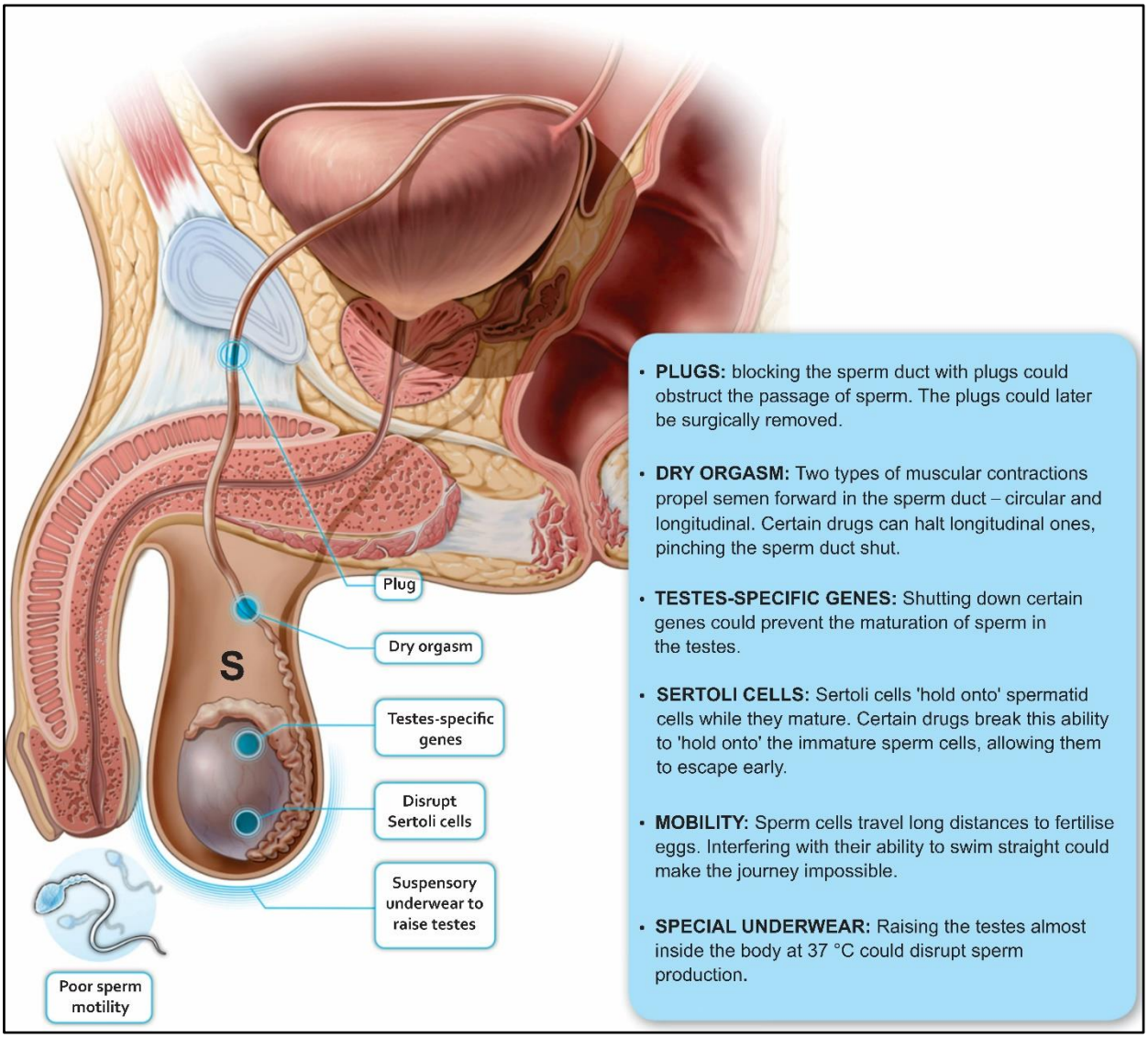


[Adapted from: Thirumalai A and Amory JK 2021. Emerging approaches to male contraception. *Fertility & Sterility* 115(6): 1369–76]
[Figure 1.1: Molnar C and Gair J 2015. Chp 24.4 Hormonal control of human reproduction. In: Concepts of Biology. 1st Ed.]
Figure 1.2: [Cornejo-Guerra C et al 2024. Consequences of exposure to low oxygen associated with high altitude on spermatogenesis and seminal parameters: A literature review. *Cells* 13(7): 592]

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3. Potential strategies to lower sperm count for birth control

Figure 1.3: Proposed strategies to lower male sperm counts as a means of contraception



[Adapted from: Amory JK 2020. Development of novel male contraceptives. *Clinical & Translational Science* 13: 228–237; and <http://pharmaceutical-journal.com/article/ overcoming-challenges-in-developing-male-contraceptives>]
[Figure 1.3: Kean S 2012, Reinventing the pill: Male Birth Control. *Science* 338(6105): 318–320]

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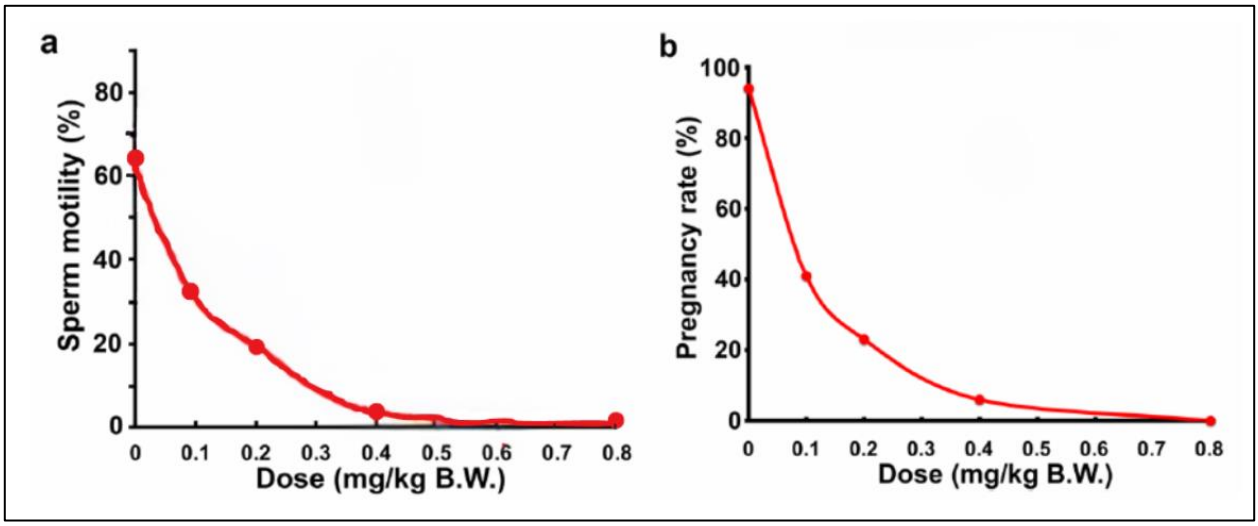
4. A new option for male contraception

Certain proteins, that control the maturation of sperm cells, are ideal targets for male contraceptives. Drugs targeting these proteins would produce non-functional, deformed sperm incapable of fertilisation without reducing testis size or sperm counts significantly.

A promising non-hormonal male contraceptive compound, **triptonide**, was identified from *Tripterygium wilfordii Hook F*, a Chinese herb plant traditionally used to treat inflammatory diseases. In the 1980s, prolonged use of this herb was linked to male infertility due to reduced sperm counts and deformed sperm. Since then, researchers have isolated several compounds from the herb, focusing on their anti-sperm effects.

The compound triptonide has shown nearly ideal contraceptive properties in male mice and crab-eating monkeys. Administered orally, triptonide caused infertility within 3–4 weeks of daily treatment, maintained infertility with continued use, and restored fertility within weeks of discontinuation (3–4 weeks for mice, 5–6 weeks for monkeys). Importantly, it caused no detectable organ damage and preserved testosterone, FSH, LH levels, and sex drive.

Figure 1.4: The results showing the effect of different triptonide concentrations (mg/kg B.W. (= Body Weight), administered daily over 4 weeks to adult male mice of ages 8–12 weeks, on sperm motility (%) and pregnancy rate (%) when each male mouse was mated with three fertile adult female mice



These findings suggest triptonide could be a breakthrough in male contraception. Its effectiveness, reversibility, and safety make it a strong candidate for further testing and potential use in humans.

[Source Material and Figure 1.4 adapted from: Chang Z et al 2021. Triptonide is a reversible non-hormonal male contraceptive agent in mice and non-human primates. *Nature Communications* 12:1253]

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QUESTION 2

Read the information below. Use this information, as well as your own knowledge, to answer Question 2 in the question paper.

AGRICULTURAL PRODUCTION OF THE MARULA TREE AS A SUSTAINABLE WAY OF IMPROVING RURAL LIVELIHOODS

1. Socio-economic importance of the marula tree

The marula tree (*Sclerocarya birrea*) (Figure 2.1) is a medium-sized deciduous tree (loses its leaves during the dry season) indigenous to sub-Saharan Africa, thriving in warm, dry climates and savanna ecosystems. Marula trees bear clusters of small red and yellow flowers, which when fertilised, produce small greenish yellow fruits.

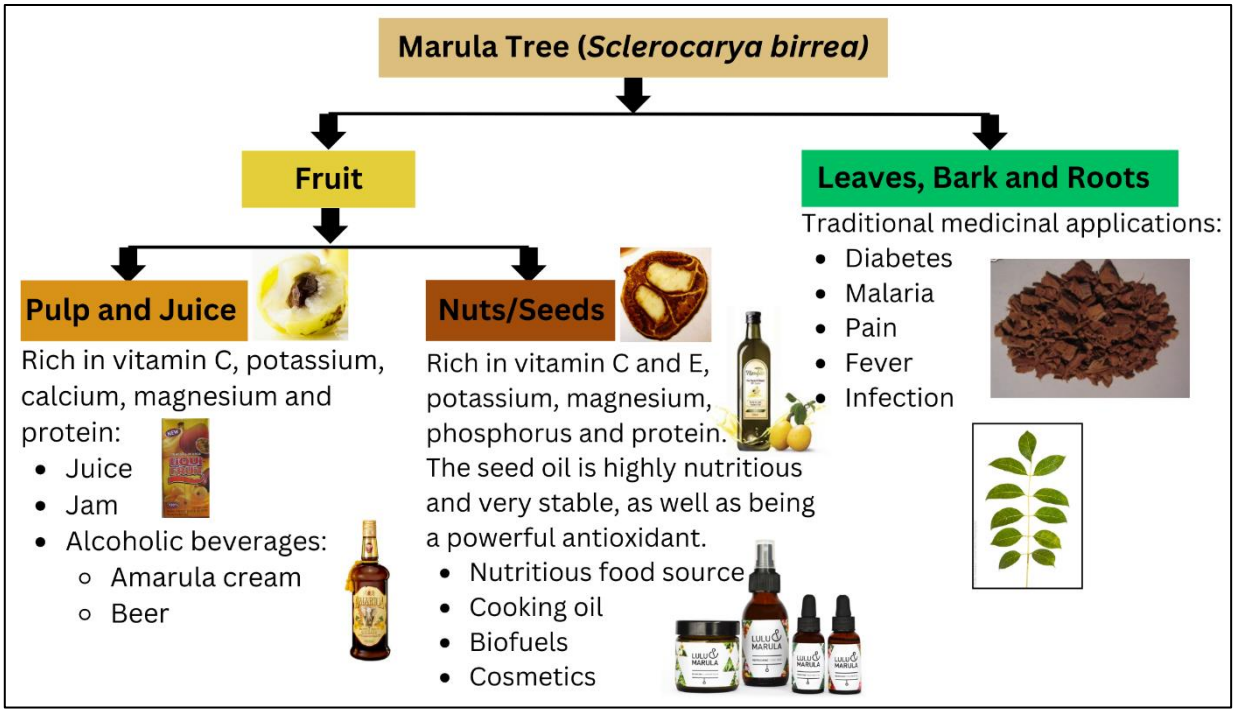


Figure 2.1: The marula tree with its fruits and seeds

[Figure 2.1 adapted from**:** [Lodhi S and Vadnere GP 2019. 2 – Health-Promoting Ingredients in Beverages. In: (Eds) Grumezescu A & Holban A. Value-Added Ingredients & Enrichments of Beverages, Academic Press, Pages 37–61]

The marula tree holds immense socio-economic importance in Southern Africa, contributing to food security, nutrition, and rural income generation (Figure 2.2).

Figure 2.2: Marula tree parts and their commercial, nutritional and medicinal uses



[Figure 2.2 adapted from: Legodi LM et al 2022. Marula tree: From fruit to wine through spontaneous fermentation & potential of deriving other value-added products. *Processes* (10): 1706; <https://en.wikipedia.org/File:Sclerocarya_birrea_-_Seed.jpg; <https://luckypony.co.za/tag/lulu-marula-skincare-products/>; <https://www.flickr.com/photos/>; <https://www.vendio.com/stores/Mngoma/umganu-african-medicine-sclero/>; and <https://www.google.com/mothercityliquor.co.za/products/amarula-cream-liqueur>]

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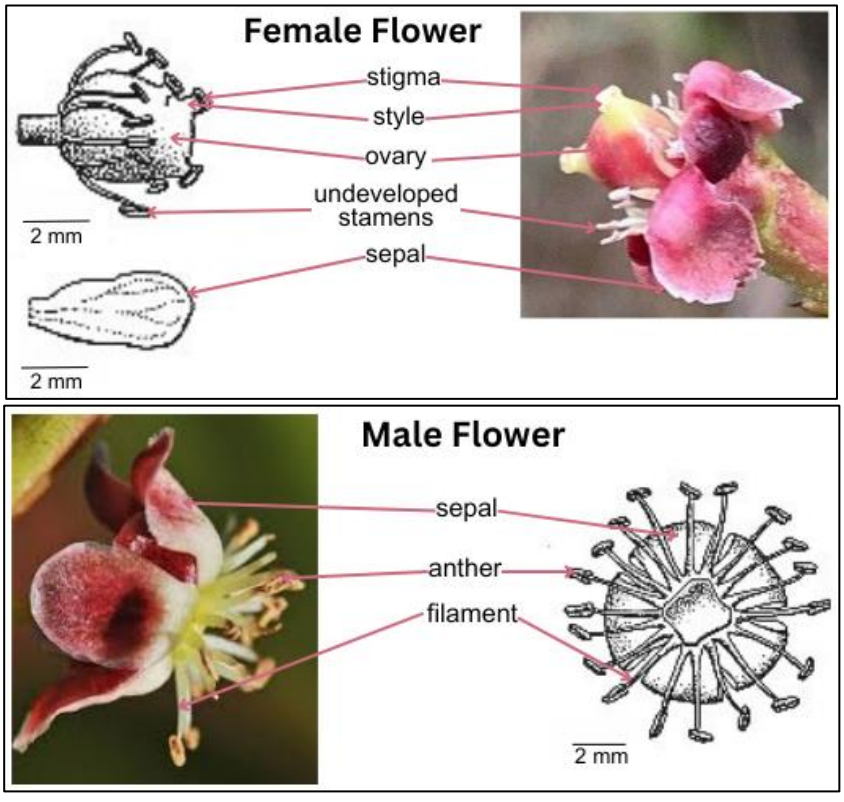
Despite most marula trees, still remaining in the wild, scientists are working on asexual and sexual reproductive methods to improve marula tree production as an agricultural crop. Existing farmers are encouraged to include the commercial planting of marula trees as a cash crop to increase their sources of income and to reduce the unsustainable harvesting of wild marula trees. These efforts aim to promote indigenous fruit trees as valuable resources for combating malnutrition and poverty.

[Adapted from: Leakey RRB et al 2022. The future of food: Domestication & commercialization of indigenous food crops in Africa over the third decade (2012–2021). *Sustainability* 14:2355; and Sileshi GW et al. 2023. Potential of indigenous fruit trees in enhancing nutrition, income & biodiversity conservation in African agroforestry. In: Dagar et al., Gupta and Sileshi (eds.) Agroforestry for sustainable intensification of agriculture in Asia & Africa, Springer Nature, Singapore Pte Ltd.]

2. Flowering in marula trees

Marula trees have male and female flowers on separate trees. Small clustered, scentless flowers have red sepals and yellow petals. Flowers, containing nectar, attract various pollinators, including bees and flies. In South Africa, marula trees flower from September to November, producing fruits from February to June. Marula trees produce pale yellow, 3–4 cm fruits weighing 15–25 g, with juicy pulp. Fruits fall green from the tree and ripen on the ground, turning yellow and softening. Trees can start producing seeds by five years old. Marula trees are highly productive, with seed-grown trees yielding 50 000 to 90 000 fruits annually under favourable conditions.

Figure 2.3: Morphology of the Female and Male flower of the Marula tree
(Male Flower photo credit: David Becking)



[Source Material and Figure 2.3 adapted from: <https://treesa.org/sclerocarya-birrea/>; <https://earthone.io/plant/sclerocarya-birrea>; and Komane B et al. 2023. Chapter 21 – *Sclerocarya birrea*. In: The South African Herbal Pharmacopoeia: Monographs of Medicinal and Aromatic Plants pages 471–501. Academic Press]

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3. Agricultural production through sexual and asexual methods

Studies in southern Africa show evidence of farmers selecting marula trees for desirable traits, like larger fruit and higher yields, over time. Trees in cultivated fields have been shown to yield up to five times more fruit than those in natural woodlands.

Sexual Reproduction:

While marula trees can successfully be germinated from seed (Figure 2.4), their mass propagation for commercial use is made difficult by the following:

1. Separate male and female trees are required for cross-pollination and fruit development.
2. Marula seeds often remain dormant in the soil for over six months.
3. Seedlings take approximately 6–10 years to produce their first fruits.

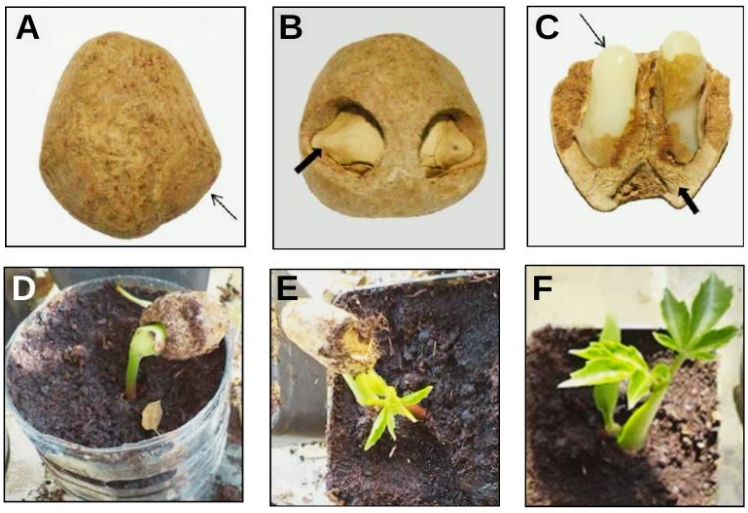


Figure 2.4: Marula propagation from seed. **(A)** An intact marula seed after removal of the fruit pulp. Arrow indicates the tough protective covering, a potential barrier to germination, through which the radicle (first root) emerges. **(B)** The covering removed, with two separate seeds revealed. The solid arrow indicates the position of the embryo. **(C)** Section of a marula seed showing walls of the stony outer layers (solid arrow) and the true seeds (fine arrow). **(D)** Emerging radicle (first root). **(E)** Plumule (first shoot) with first leaves. **(F)** Young seedling.

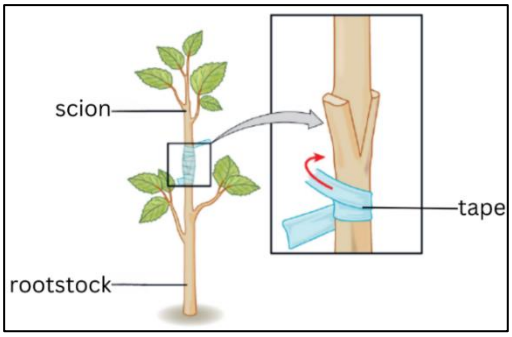
Asexual Reproduction:

Asexual reproduction offers advantages for marula cultivation and can ensure superior genetic traits are preserved by replicating trees with desirable qualities. Farmers prefer to plant female trees due to their fruit production.

A. Grafting, as means of asexual reproduction, has proven to be particularly effective, yielding earlier flowering, consistent fruit quality, and reducing the immature growing phase to four years.

Grafting, a propagation method in which tissues from one plant are joined to another to grow as a single plant, has proven successful in southern Africa. The seedling providing the roots is grown from seed and is called the rootstock. The plant contributing stems, leaves, flowers, or fruits is typically cut from an existing productive female tree and is called the scion. For grafting to work, the tissue layers of the rootstock and the scion must touch and remain alive until they fuse.

Figure 2.5: Example of the cleft graft for the vegetative propagation of marula



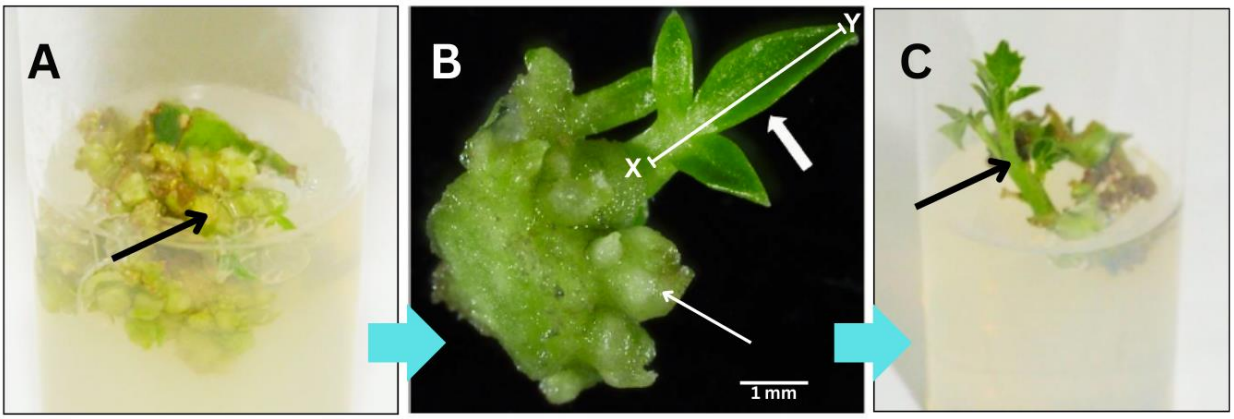
Cleft grafting, typically done at the start of the growing season, inserts a thin wedge-shaped scion into a cut on a thicker rootstock's edge. The graft is then secured with tape and sealed with wax to prevent drying and water entry (Figure 2.5).

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B. Tissue culture

A laboratory-based research study demonstrated the potential for the large-scale tissue culture of marula trees. Leaf explants (small samples of young leaf material used as a starting material to grow a new plant in tissue culture) from a marula tree seedling, with desired genetic traits for agricultural production, were cultured on growth media enriched with vitamins, sucrose, and plant growth hormones, then maintained at 25 °C under UV lights for 16 hours per day. After 2 weeks, explants showed growth and the development of small globular structures resembling embryos (Figure 2.6A). These structures became more defined after 4 weeks, with some forming leaf-like structures (Figure 2.6B). Further shoot growth was demonstrated from leaf explants after 8 weeks (Figure 2.6C).

Figure 2.6: (A) Tissue culture from marula leaf explants after 2 weeks, showing expansion and development of small globular structures (arrow). **(B)** A stereomicrograph showing chlorophyll containing small globular embryo-like structures (fine arrow) and a shoot-like structure (solid arrow) after 4 weeks. **(C)** Further shoot growth (arrow) from leaf explants after 8 weeks



[Adapted from: [Dos Santos JRP et al. 2024. Methods for overcoming seed dormancy and vegetative propagation of marula. *Revista de Ciências Agrárias* 47(2): 394–401; Mng'omba SA et al 2012. Scion & stock diameter size effect on growth & fruit production of *Sclerocarya birrea* (marula) trees. *Journal of Horticulture & Forestry* 4(9): 153–160; Motlhanka DM and Makhabu SW 2011. Medicinal & edible wild fruit plants of Botswana as emerging new crop opportunities. *Journal of Medicinal Plants Research* 5(10): 1836–1842; and <https://heritagefruittrees.wordpress.com/2012/09/17/the-cleft-grafting-process/>]
[Figure 2.4: <https://www.youtube.com/watch?v=bp2nFmrT_XA>]
[Figure 2.5: Production of marula (*Scelerocarya birrea)* seedlings. Plant Production. DAFF, Pretoria, 2013]
[Figure 2.6 & Text: [Moyo M 2009. Micropropagation and secondary metabolites of *Sclerocarya birrea*. PhD Thesis, UKZN]

4. Seed banks and food security

Natural marula tree populations are threatened by agricultural expansion, overgrazing, and exploitation, making conservation efforts crucial. Marula seeds are considered long lasting and can be stored in seed banks. Collections of marula seeds have been made across Africa to support both domestication and conservation efforts. Seeds have been collected from countries like South Africa, Namibia, Burkina Faso, Kenya, Tanzania, and Togo for tree seed centres. Marula seeds can be stored for long periods, with viability lasting up to four years. These seed collections play a vital role in preserving the marula tree's genetic diversity.

[Adapted from: Fajinmi OO 2023. Propagation of medicinal plants for sustainable livelihoods, economic development & biodiversity conservation in South Africa. *Plants* 12: 1174; and Muok BO et al 2012. Conservation and sustainable use of genetic resources of priority food tree species in sub-Saharan Africa: *Sclerocarya birrea* (Marula). Produced by the SAFORGEN Food Tree Species Working Group]

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SECTION B

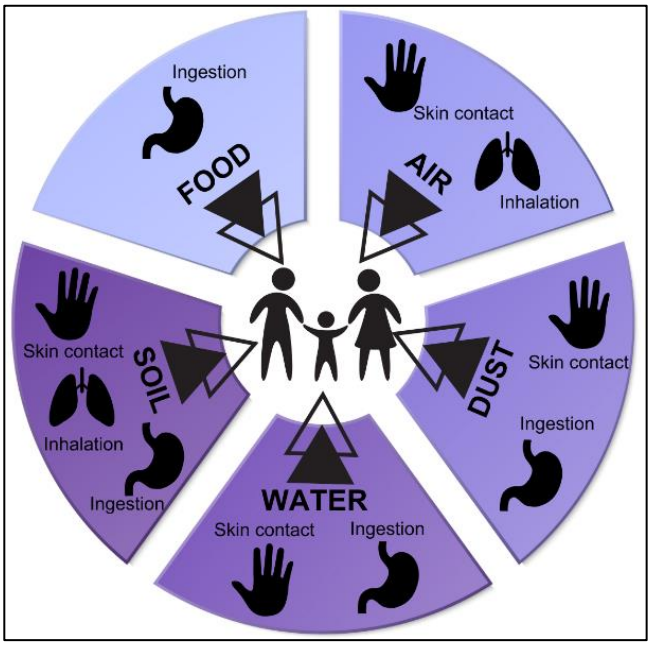
QUESTION 3

Read the information below. Refer to this information, as well as your own knowledge, to answer Question 3 in the question paper.

SOURCE A Endocrine Disrupting Chemicals

Endocrine Disrupting Chemicals (EDCs) are substances that interfere with the normal functioning of the endocrine system. These chemicals can mimic, block, or alter hormone activity, leading to a variety of health issues, including impaired fertility in both men and women. Over the past decade, there has been significant progress in understanding how endocrine disrupting chemicals (EDCs) affect human fertility. These chemicals, found in everyday products like plastics, cosmetics, food packaging, and pesticides, can enter the environment during their production, use, or disposal. Humans are exposed to EDCs primarily through contaminated food and water, inhaling polluted air or household dust, and skin contact (Figure 3.1) with products like cosmetics and plastics.

Figure 3.1: Routes of exposure to EDCs, with each source showing the pathways of EDC uptake



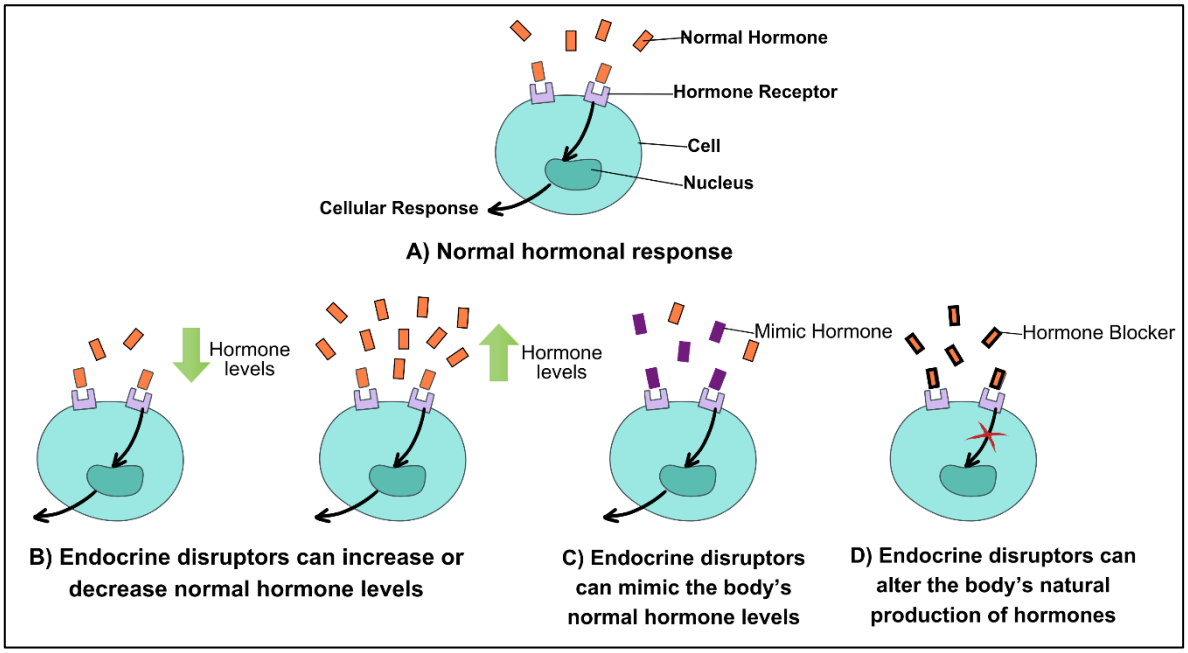
Even small amounts of EDCs can interfere with hormones that control reproduction, increasing the risk of fertility issues. EDCs can persist in the environment or in the body, where they may disrupt hormone function, affecting long-term reproductive health. The table below summarises the effects of the four main categories of EDCs on male fertility.

EDC Category	Primary Sources	Effects on Men	Primary Mechanism
BPAs	• Plastics • Canned foods • Till invoices	• Reduced sperm quality • Altered testosterone levels	Behave like oestrogen in the human body
Phthalates	• Plastics • Personal care products	• Decreased sperm count • Lowered testosterone production	Preventing testosterone from binding to receptors on testis cells
Pesticides	• Crops • Household products • Water	• Oxidative stress • Altered sperm structure	Disrupts hormone receptors on cells
Dioxins	• Industrial by-products • Fatty foods	• Reduced sperm counts • Altered hormone levels	Interferes with the ability of reproductive hormones to function

[Adapted from: Bergman A et al 2012. State of the science of endocrine disrupting chemicals. United Nations Environment Programme (UNEP) and the World Health Organization, WHO Press, Switzerland]
[The UNEP is responsible for coordinating responses to environmental issues within the United Nations]

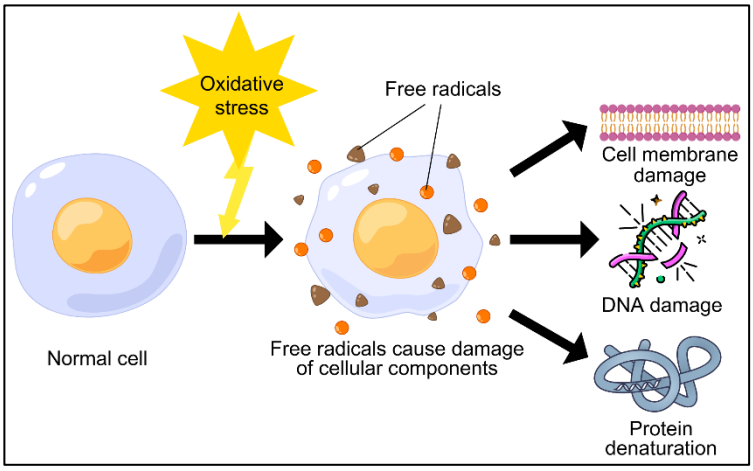
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How endocrine disrupting chemicals affect hormonal responses at a cellular level



[Image adapted from: The impact of endocrine disruptors on health. By Dr Sanchari Sinha Dutta, May 30, 2022. <https://www.news-medical.net/health/The-Impact-of-Endocrine-Disruptors-on-Health>]
[News Medical: is an online, medical information provider for healthcare and life science professionals]

Oxidative stress



[Image adapted from: <www.shutterstock.com>]

Oxidative stress (Figure 3.2) occurs when reactive oxygen 'substances' (ROS), also known as free radicals, exceed the body's ability to neutralise them with antioxidants. They are produced naturally during processes such as metabolism and immune responses.

Figure 3.2: Simplified diagram illustrating the cellular effects of oxidative stress

Oxidative stress can harm both oocytes and sperm cells by damaging the DNA of these cells, disrupting gene expression, leading to problems with sperm/oocyte development, fertilisation, embryo development, or implantation. For women, oxidative stress can directly harm ova or prevent a healthy uterine lining developing to support an embryo. This can lead to miscarriage, poor embryo development, and complications during pregnancy.

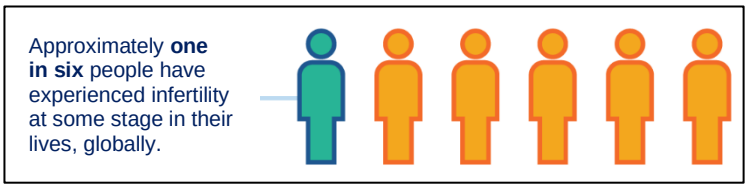
Different types of EDCs can reduce the ability of antioxidants to neutralise ROS. Glutathione, a powerful antioxidant naturally produced in the body, neutralises free radicals, repairs ROS-induced damage, and maintains other key antioxidants like vitamins C and E in their active forms. Factors such as poor diet, stress, toxins, and aging can deplete glutathione levels.

[Adapted from: Adeoye O et al 2018. Review on the role of glutathione on oxidative stress and infertility. *JBRA Assisted Reproduction* 22(1):61–66]
[JBRA Assisted Reproduction is a peer-reviewed publication of Brazilian Society of Assisted Reproduction]

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SOURCE B Global fertility trends

Infertility is a disease of the male or female reproductive system defined by the failure to achieve a pregnancy after 12 months or more of regular unprotected sexual intercourse. A growing body of scientific evidence indicates that reproductive health, and ultimately reproductive capacity, is declining globally. It has been reported that the number of families applying to infertility clinics to have a child with the assisted reproductive techniques has increased significantly in recent years.



The current global population is 8,2 billion (January 2025), with growth expected to continue, reaching 9,7 billion by 2050 and 10,4 billion by 2100. While global population growth has slowed to less than 1% per year, many Higher Income Countries, particularly in Europe and parts of Asia, are experiencing population decline due to fertility rates below the replacement level of 2,1 children per woman. Globally, the total fertility rate (TFR) has dropped from 5 in 1950 to 2,3, with further declines expected (Figure 3.3).

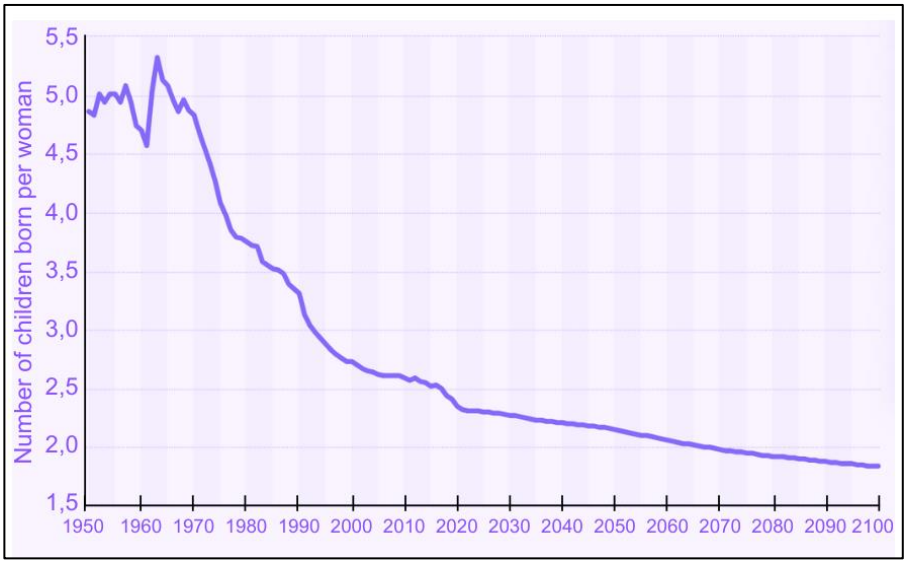


Figure 3.3: Total global fertility rate from 1950 to 2021, with projections until 2100 (in no. of children per woman).

[Adapted from: Yazar S 2022. Endocrine Disruptors and Infertility. *IntechOpen* Doi:10.5772]
[*IntechOpen* is an Open Access publisher of academic books and journals in all fields of Science]

Population density

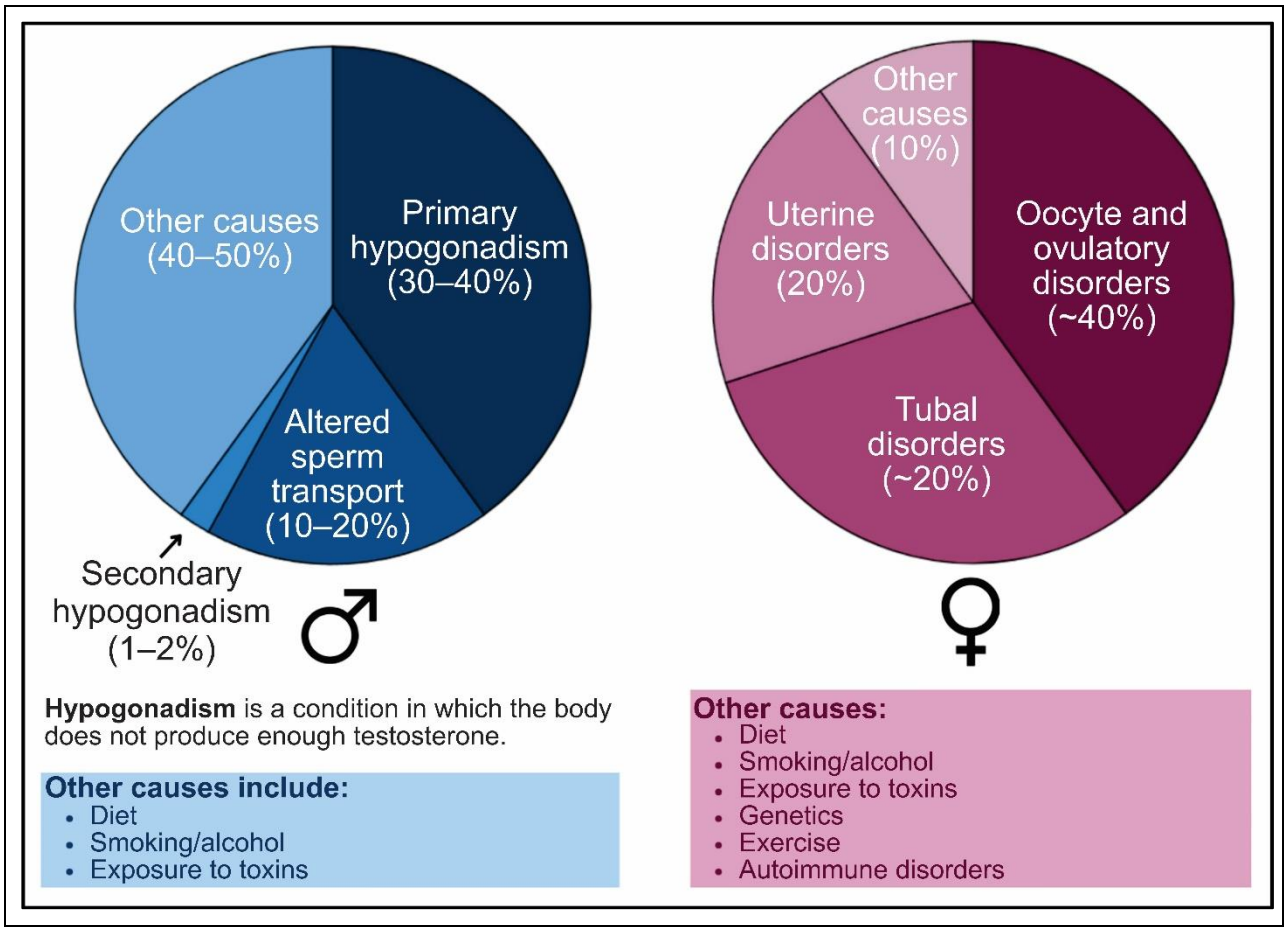
Global birth rates are declining, but there is significant regional variation. In lower income countries, high fertility rates and a youthful population structure contribute to population growth. In contrast, higher income countries face below-replacement fertility, fewer children, and an aging population, leading to challenges in elderly care and old age security.

Studies suggest that higher population density is linked with reduced fertility. Factors like limited living space and increased costs of raising children, such as housing and education, contribute to this decline. Additionally, stress and environmental pollutants may further reduce fertility.

[Adapted from: Lutz W et al 2006. Population density is a key factor in declining human fertility. *Population & Environment* 28: 69–81]
[*Population & Environment* is a peer-reviewed journal covering research on population & the environment]

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SOURCE C Primary causes of infertility



[Adapted from: How common is infertility? By CNY Fertility. Updated July 12, 2024. <https://www.cnyfertility.com/how-common-is-infertility/>]

[*CNY Fertility:* is a CNY is a fertility clinic offering infertility & genetic testing, basic treatments and advanced surgical techniques]

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SOURCE D Hormonal factors affecting fertility

How hormonal imbalance affects fertility

Hormones regulate key body functions like reproduction, growth, and metabolism. A hormonal imbalance can disrupt ovulation, making conception difficult. Thyroid imbalances can cause ovulatory dysfunction, while a short luteal phase from low progesterone levels can prevent proper implantation, leading to fertility issues.

[Adapted from: <https://www.jprobertsobgyn.com/blog/>]
[Dr John Roberts is a board-certified obstetrician/gynaecologist situated in Plano, Texas, USA]

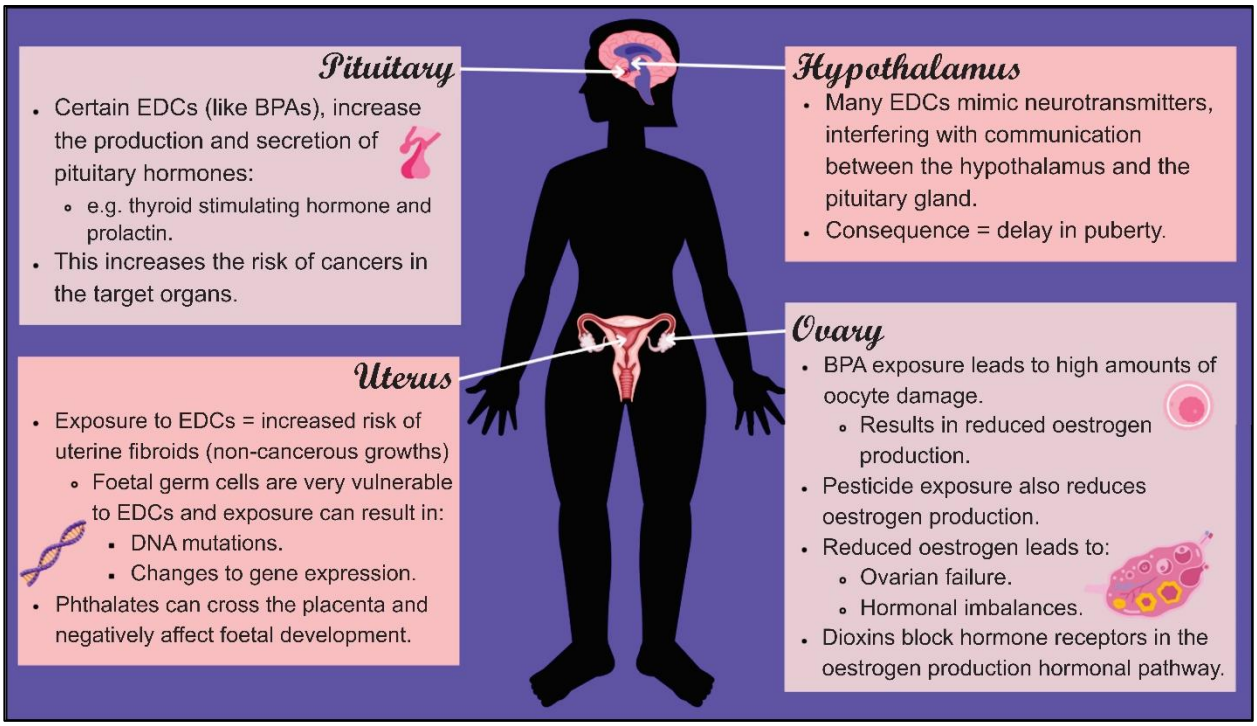
Polycystic ovaries

Polycystic ovary syndrome (PCOS) is a common hormonal disorder in women, marked by irregular ovulation, and multiple cysts forming on the ovaries. Many women with PCOS also experience obesity and insulin resistance. While the exact causes of PCOS are unclear, both genetic and environmental factors are thought to play a role. Research suggests BPA may interfere with insulin function and glucose metabolism, contributing to insulin resistance. Studies have found higher BPA levels in women with PCOS compared to others.

[Adapted from: Marques-Pinto A et al 2013. Human infertility: are EDCs to blame? *Endocrine Connections* 2: R15–R29]
[*Endocrine Connections* is a peer-reviewed journal, publishing articles on all areas of endocrinology]

How EDCs affect female endocrine and reproductive organs

EDCs are associated with diseases such as PCOS and endometriosis, spontaneous abortions, birth defects, breast cancer, premature ovarian failure. Females are at a greater risk than men, especially with the rise in environmental oestrogens.



[Adapted from: Silva ABP et al 2023. The role of endocrine disruptors in female fertility. *Molecular Biology Reports* 50:7069–7088]
[Molecular Biology Reports is a peer-reviewed scientific journal covering research on molecular processes]
Rattan S et al 2017. Exposure to EDCs: consequences for female fertility. *J. of Endocrinology* 233: 109–29
[Journal of Endocrinology is a peer-reviewed journal focusing on endocrine physiology and metabolism]

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SOURCE E Environmental factors affecting fertility

Radioactivity

Exposure to high levels of radiation can have serious effects on human fertility due to its ability to damage cells. Radiation exposure can harm male fertility by damaging sperm DNA, causing mutations and reduced fertility. High doses may destroy sperm-producing cells, leading to temporary or permanent infertility. It can also disrupt testosterone production, and damaged sperm may pass mutations to offspring.

In women, radiation exposure can damage oocytes, reduce oocyte supply, and lead to early menopause. High doses may harm ovarian tissue, disrupting hormone production and menstrual cycles. It also increases miscarriage risk, and damaged oocytes may cause genetic defects or developmental issues in offspring.

[Adapted from: Feichtinger W 1991. Environmental factors and fertility. *Human Reproduction* 6(8): 1170–1175]
[*Human Reproduction* is a peer-reviewed scientific journal covering all aspects of human reproduction]

Primary ovarian failure

Primary ovarian failure (POF) affects about 1% of women under 40, causing reproductive issues and early menopause. POF may result from accelerated cell death, blocked follicle maturation, or premature follicle development. Possible causes include genetic mutations, metabolic disorders, viral infections, treatments like chemotherapy, autoimmune conditions, and environmental factors such as smoking and toxins. EDCs may also play a role by promoting multi-oocyte follicles, which could lead to POF.

[Adapted from: Costa EMF et al 2013. Effects of endocrine disruptors in the development of the female reproductive tract. *Brazilian Archives of Endocrinology & Metabolism* 58(2): 153–161]
[Brazilian Archives of Endocrinology & Metabolism is a peer-reviewed journal that publishes scientific articles on themes in Endocrinology and Metabolism]

Heavy-metal exposure

Increased industrialisation has led to increased human exposure to heavy metals such as lead, mercury, cadmium, and arsenic (toxic elements present in polluted air, water, soil, and certain foods). These heavy metals can remain in the body for long periods and accumulate in fatty tissues or organs, disrupting hormone signals and leading to poor sperm quality, irregular ovulation, and increasing miscarriage risk. By damaging reproductive cells, they reduce fertility. Exposure occurs through inhaling polluted air, drinking contaminated water, eating food grown in polluted soil, or handling industrial materials.

[Yazar S 2022. Endocrine Disruptors and Infertility. *IntechOpen* <doi:10.5772]
[*IntechOpen* is an Open Access publisher of academic books and journals in all fields of Science]

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SOURCE F Lifestyle factors affecting fertility

Personal choices

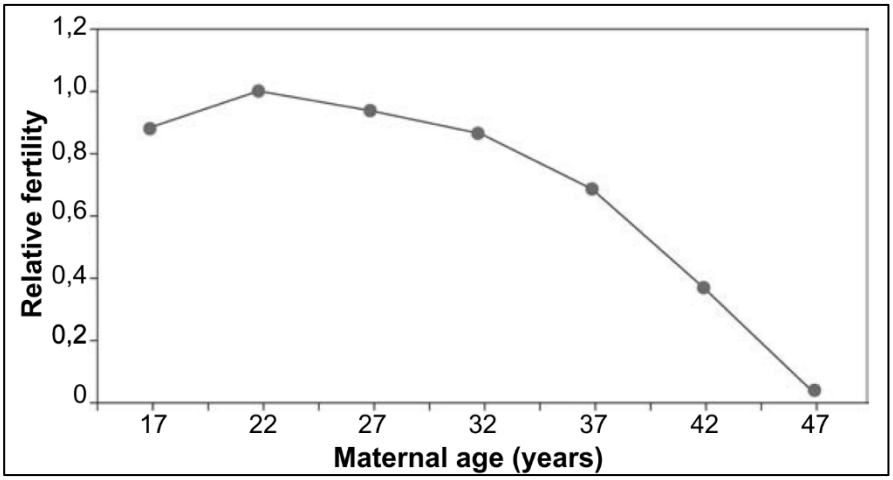
In many high-income countries, the average age of having a first child has been increasing, leading to smaller family sizes. This is due to age-related declines in fertility and more couples choosing to remain 'child-free'. In contrast, countries like India and those in sub-Saharan Africa have much younger average ages for first births. Older age at first birth can create a cycle, as daughters of older mothers are more likely to remain childless. Professional careers also contribute to delayed childbirth, with female doctors having an average age of 32 for their first child, compared to 27 for non-doctors.

[Adapted from: Anderson RA and Hickey M 2023. Reproduction in a changing world. *Fertility & Sterility* 120(3): 415–420]
[*Fertility & Sterility* is an international peer-reviewed journal of infertility and human reproductive disorders]

Maternal age

Infertility increases with maternal age due to a decline in both the quantity and quality of eggs (Figure 3.4). Women are born with approximately 2 million ova, which decreases to about 25 000 by age 37. Aging also affects ova quality, increasing the likelihood of chromosomal abnormalities. These abnormalities can lead to failed fertilisation or halted embryo development, contributing to reduced fertility in older women.

Figure 3.4: Relative fertility graphed according to maternal age



[Adapted from: Bayer SR 2012. Factors affecting infertility. In: Bayer SR et al (Eds). The Boston IVF Handbook of Infertility (3rd Edition). Pages 11–18. Informan Healthcare, London]
[The handbook of infertility is a published book edited (this specific chapter is written) by Dr. Steven Bayer, MD who is an obstetrician/gynaecologist in Waltham, Massachusetts.]

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Nutritional factors that have a negative effect on male fertility:

Nutritional Factor	Resultant Effect on Fertility
Trans fatty acids	➢ Cause abnormalities in certain metabolic pathways and damage the metabolism of essential components of the reproductive system in males. ➢ High intake causes significant decline in sperm concentration and sperm count.
Sugar	➢ Decreases sperm motility.
Soy foods	➢ High intake decreases sperm concentration.
Dairy products	➢ Consumption of whole-fat dairy products decreases sperm motility and negatively alters sperm morphology.
Processed meat	➢ Associated with lower sperm counts, abnormal sperm morphology and lower sperm motility.
Vegan diet	➢ Vegans had lowest hyperactive sperm motility. ➢ Vegetables-based food intake decreases sperm quality.
Carbohydrates	➢ Energy derived from carbohydrates is associated with lower semen volume.
GMOs	➢ The GMO food can negatively influence endocrine metabolism.

[Adapted from: Çekici H 2018. Current nutritional factors affecting fertility and infertility. *Annals of Clinical & Laboratory Research* 6(1): 225]
[Annals of Clinical & Laboratory Research is an international peer-reviewed journal that publishes articles in all areas of Clinical and Laboratory sciences]

The effect of lifestyle habits on fertility

Habit	Men/Women	Effect on Fertility
Caffeine	Women	• > 4 cups of coffee per day reduced the ability to conceive by 20% • > 8 cups of coffee per day increased the risk of spontaneous abortions
Smoking	Men	• > 20 cigarettes per day negatively affected sperm count and motility
	Women	• smoking during pregnancy increased the risk of miscarriage
Weight	Women	• **Overweight:** linked to insulin resistance and decreased levels of oestrogen regulation • **Underweight:** may experience irregular ovulation, stop ovulating or stop menstruating
Chronic Alcoholism	Women	• A decrease in pregnancy rate • An increased risk of spontaneous abortion
Stress	Women	• Can cause irregular menstrual cycles • Stress hormones, like cortisol disrupt signalling between the brain and ovaries

[Adapted from: Feichtinger W 1991. Environmental factors and fertility. *Human Reproduction* 6(8): 1170–1175]
[Human Reproduction is a peer-reviewed scientific journal covering all aspects of human reproduction]
[Soto E and Copperman AB 2011. Chapter 1: Factors affecting fertility. In: Seli E (ed) Infertility (1st edition). Pages 1–7. Blackwell Publishing LTD]
[Infertility is a published book edited by Emre Seli, MD, is a Professor of Obstetrics, Gynaecology, and Reproductive Sciences at Yale School of Medicine, and the Medical Director of Yale Fertility Centre]

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SOURCE G Genetic factors affecting fertility

Genetic factors play a significant role in infertility, contributing to nearly 30% of cases of infertility. Genetic disorders can impair fertility in both males and females. In females, Turner syndrome, Fragile X, and Kallmann syndrome affect ovarian development and hormone production. In males, Klinefelter syndrome, Y-chromosome microdeletions, CFTR gene mutations, and Kallmann syndrome reduce sperm production or block sperm transport, leading to infertility.

[Adapted from: Zorrilla M et al 2013. The Genetics of Infertility: Current Status of the Field. *Current Genetic Medicine Reports* 1(4):1–17]

[*Current Genetic Medicine Reports:* publishes research across the full range of disciplines related to genetic medicine. Note this journal is not peer-reviewed]

[How much of infertility is genetic? By Dr. Jill Seladi-Schulman Jul 25, 2022. <https://www.healthline.com/health/womens-health/is-infertility-genetic>]

[Healthline is a popular health information website that provides articles related to health. Its content is reviewed by medical professionals]

Multi-generational effects of EDCs

Endocrine disruptors can harm human reproductive development, affecting fertility in exposed individuals and future generations. For example, offspring of women treated with DES, a synthetic oestrogen that was widely prescribed to pregnant women from the 1940s to the 1970s to prevent miscarriages, preterm labour, and other pregnancy complications, showed reproductive abnormalities, and a recent study links DES exposure to higher rates of genital malformations in grandchildren, likely due to changes in the gene that controls the production of testosterone/oestrogen receptors, located on the X-chromosome, and therefore passed through the female germline.

Male germ cells are particularly sensitive to damage because they have unique chemical tags, called methylation markers, that control how genes are expressed. These markers can be easily disrupted, making germ cells more vulnerable to harmful environmental influences and therefore unable to fertilise an ovum.

[Adapted from: Marques-Pinto A and Carvalho D 2013. Human infertility: are endocrine disruptors to blame? *Endocrine Connections* 2: R15-R29. <DOI: 10.1530/EC-13-0036>]

[*Endocrine Connections* is a peer-reviewed journal, publishing research in all areas of endocrinology]

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