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Flower Pigments and Their Role in Flower Coloration

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INTRODUCTION

The vibrant and diverse colours of flowers are not just visually appealing—they play a crucial role in attracting pollinators and ensuring plant reproduction. These colours are primarily the result of specific natural pigments present in the flower petals. The type, concentration, and combination of pigments, along with cellular pH and light conditions, determine the final flower colour.

Major Flower Pigments and Their Colours

1. Anthocyanins

- **Colour Range**: Red, pink, purple, blue
- **Type**: Water-soluble flavonoids
- **Location**: Vacuoles of petal cells
- **Examples**:
  - Red roses and geraniums
  - Purple petunias
  - Blue delphiniums

Note: pH affects anthocyanin colour—acidic pH yields red, neutral gives purple, and alkaline leads to blue.

2. Carotenoids

- **Colour Range**: Yellow, orange, red
- **Type**: Lipid-soluble terpenoids
- **Location**: Plastids (chromoplasts)
- **Examples**:
  - Yellow marigold
  - Orange calendula
  - Red sunflower varieties

Carotenoids also contribute to photosynthesis and antioxidant activity in plants.

3. Flavonoids (excluding anthocyanins)

- **Colour Range**: Pale yellow, ivory, UV-visible (not always visible to humans)
- **Examples**:
  - Ivory tulips
  - White magnolias

Some flavonoids absorb UV light, guiding pollinators like bees which can see UV patterns.

4. Betalains *(exclusive to Caryophyllales family)*

- **Colour Range**: Red, violet (betacyanin's); yellow to orange (betaxanthins)
- **Examples**:
  - Red and yellow beetroot
  - Bougainvillea
  - Portulaca

Summary of Flower Pigments: Chart + Expanded Academic Overview

I. Chart: Pigments, Their Colours, and Examples

Pigment Group	Main Pigments	Colour Range	Solubility	Examples in Flowers
Anthocyanins	Cyanidin, Delphinidin, Pelargonidin	Red, purple, blue	Water-soluble (vacuoles)	Rose, Petunia, Delphinium
Carotenoids	β-Carotene, Lutein, Zeaxanthin	Yellow, orange, red	Lipid-soluble (plastids)	Marigold, Calendula, Sunflower
flavanols / Flavones	Kaempferol, Quercetin, Apigenin	Pale yellow, white, UV-visible	Water-soluble (vacuoles)	Tulip (white), Daisy, Magnolia
Betalains	Betacyanin, Betaxanthin	Red/violet, yellow/orange	Water-soluble (vacuoles)	Bougainvillea, Portulaca
Chlorophylls	Chlorophyll a and b	Green	Lipid-soluble (chloroplasts)	Green bracts (e.g., Heliconia)

II. Expanded Academic Section: Pigments and Their Biosynthesis

1. Anthocyanins

- **Structure**: Flavonoid-based (C6-C3-C6)
- **Precursor Pathway**: Phenylpropanoid pathway
- **Key Enzymes**:
  - PAL (Phenylalanine Ammonia Lyase)
  - CHS (Chalcone Synthase)
  - DFR (Dihydroflavonol-4-reductase)
  - ANS (Anthocyanidin synthase)
- **Colour Shift by pH**:
  - Acidic → Red
  - Neutral → Purple
  - Alkaline → Blue
- **Example of Biotech Application**:
  - *Blue rose*: Introduction of delphinidin biosynthesis genes from petunia and pansy.

2. Carotenoids

- **Structure**: Isoprenoid derivatives (C40)
- **Precursor Pathway**: MEP (Methylerythritol phosphate) pathway
- **Key Enzymes**:
  - PSY (Phytoene Synthase)
  - PDS (Phytoene Desaturase)
  - LCY-b (Lycopene β-cyclase)
- **Types**:
  - Carotenes (e.g., β-carotene)
  - Xanthophylls (e.g., lutein, zeaxanthin)
- **Functions**:
  - Flower colour
  - Light harvesting in photosynthesis
  - Precursor to vitamin A (in animals)
- **Example**:
  - **Yellow marigold**: Rich in lutein, used in eye supplements.

3. flavanols / Flavones

- **Structure**: Flavonoid sub-class (closely related to anthocyanins)
- **Colour**: Pale yellow, ivory; many are UV-absorbing but not visible to the human eye
- **Function**:
  - Co-pigmentation (enhance anthocyanin colour)
  - UV protection
  - Pollinator attraction (e.g., bees see UV patterns)

4. Betalains

- **Mutually exclusive** with anthocyanins in plants.
- **Structure**: Derived from tyrosine
- **Types**:
  - **Betacyanin's** – red to violet
  - **Betaxanthins** – yellow to orange
- **Key Enzymes**:
  - DOPA dioxygenase
  - Glucosyltransferases
- **Found In**: Only in Caryophyllales family plants
- **Example**:
  - Bougainvillea and beetroot (used as food dye – E162)

5. Chlorophylls (Occasionally in floral tissues)

- **Structure**: Porphyrin ring with magnesium
- **Colour**: Green
- **Found In**: Not usually in petals, but present in sepals, bracts, or immature flowers (e.g., hellebores)
- **Role**: Photosynthesi

III. Research & Biotech Applications in Floriculture

Trait	Pigment Involved	Biotech Strategy
Blue flower development	Delphinidin (Anthocyanin)	Gene transfer from petunia/pansy to rose/chrysanthemum
Delayed petal senescence	Anthocyanin & ethylene	Gene silencing (e.g., RNAi against ACC synthase)
Increased yellow pigmentation	Carotenoids	Overexpression of LCY-b and PSY genes
UV-pattern enhancement	Flavanol's	Gene editing or selection for flavanol biosynthesis
Non-browning white flowers	Flavonoid suppression	Downregulation of CHS to reduce yellowing

Factors Affecting Flower Colour

- **pH of petal cell vacuoles**
- **Genetic makeup and gene expression**
- **Light intensity and temperature**
- **Pigment concentration and combinations**

Applications in Floriculture

- **Breeding for novel colours** using pigment pathway manipulation
- **Biotechnology**: Introduction of pigment-related genes (e.g., blue rose via delphinidin gene)
- **Colour enhancement** through controlled growing conditions (e.g., light, pH)

Applications of Flower Pigments in Floriculture

1. Development of New Flower Colours
   - Through breeding or genetic engineering, pigment pathways are manipulated to create novel and attractive colours (e.g., blue rose, black petunia).
2. Variety Improvement for Market Demand
   - Customized colours are developed to match seasonal, cultural, or regional preferences (e.g., red for Valentine's Day, yellow for friendship).
3. Marker Traits in Breeding
   - Pigment traits (e.g., petal colour) are used as visible markers in hybrid identification or trait selection.
4. Value Addition
   - Brightly pigmented flowers are used for dyes, food colouring, or cosmetic and wellness products (e.g., hibiscus tea, rose water).
5. Pollinator Attraction
   - Specific pigments, especially those visible in UV light, enhance pollinator attraction, increasing seed set and productivity in ornamental gardens.
6. Research and Biotechnology
   - Pigment biosynthesis pathways serve as models for plant metabolic engineering and functional genomics.

CONCLUSION

Flower pigments are nature's palette, painting petals in brilliant hues through biochemical artistry. Understanding these pigments not only deepens our appreciation of floral beauty but also empowers breeders and floriculturists to develop new, market-attractive flower colours through genetic and environmental manipulation.