# Biomarkers
# - specificities & discussions -

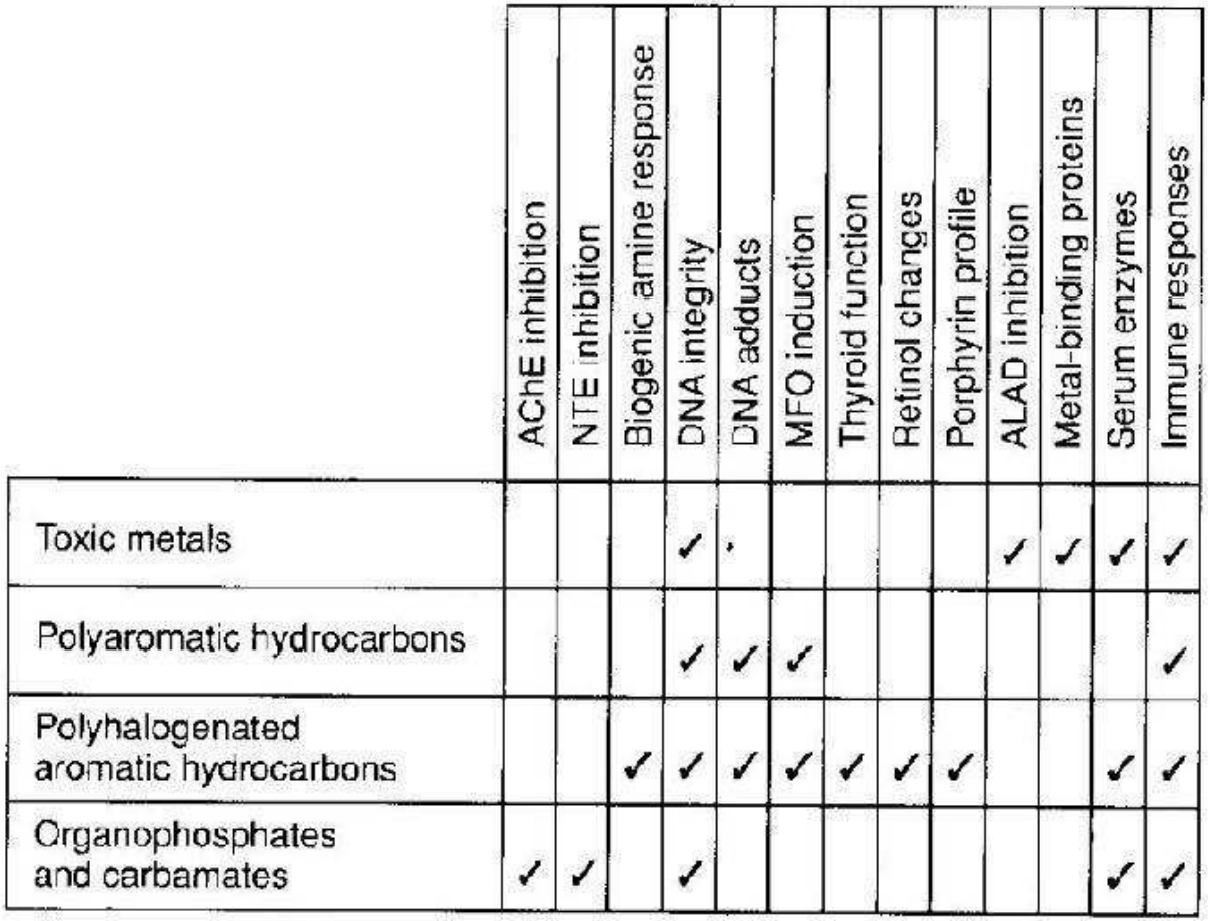



**Figure 10.1** Biomarkers available for different classes of pollutants.

**Table 10.2** Specificity of biomarkers

| | |
|---|---|
| Highly specific | Inhibition of ALAD by lead |
| Moderately specific | Inhibition of AChE by OPs and carbamates |
| | Induction of porphyria by some PHAHs |
| Relatively nonspecific | Induction of MFO enzyme systems |
| | Sister chromatid exchange |

**Table 10.3** Biomarkers for different classes of pollutants

| Environmental pollutant | Biomarker | Reliability index* |
|---|---|---|
| Toxic metals | DNA integrity | s |
| | Metal-binding proteins | s,d |
| | ALAD inhibition | s,d,p |
| | Immune response | s |
| | Levels of serum enzymes | s |
| PAHs | DNA/haemoglobin adducts | s,d,p |
| | DNA integrity | s |
| | MFO induction | s,d |
| | Immune response | s |
| PHAHs | Biogenic amines response | s |
| | DNA/haemoglobin adducts | s,d |
| | DNA integrity | s |
| | MFO induction | s |
| | Porphyrin profile | s |
| | Retinol changes | s |
| | Immune response | s |
| OPs | AChE inhibition | s,d,p |
| | Neuroesterases inhibition | s,d,p |
| | DNA integrity | s |
| | Enzyme profiles | s |
| | Immune responses | s |

* s = signal of potential problem
d = definitive indicator of type or class of pollutant
p = predictive indicator of long-term adverse effect
Expanded from Shugart *et al.* (1989).

**Table 10.4** Evaluation of biological responses to assess physiological injury caused by pollutants

| | Response is often result of exposure to pollutant | Exposure to pollutant is known to cause response in free-ranging organisms | Exposure to pollutant is known to cause response in controlled experiments | Response is practical to measure |
|---|---|---|---|---|
| | 1. Responses that meet all criteria | | | |
| Eggshell thinning | Yes | Yes | Yes | Yes |
| Reduced avian reproduction | Yes | Yes | Yes | Yes |
| ChE inhibition | Yes | Yes | Yes | Yes |
| ALAD inhibition | Yes | Yes | Yes | Yes |
| | 2. Responses that met three criteria | | | |
| MFO induction | Yes | No | Yes | Yes |
| NTE inhibition | Yes | No | Yes | Yes |
| Thyroid dysfunction | No | Yes | Yes | Yes |
| Alteration in glutathione | No | Yes | Yes | Yes |
| | 3. Responses that met two criteria | | | |
| Increased blood porphyrin | No* | No* | Yes | Yes |
| Alterations to neurotransmitter enzymes | *No* | No | Yes | Yes |
| Metallothionein induction | *No* | No | Yes | Yes |

**Table 10.4** Evaluation of biological responses to assess physiological injury caused by pollutants

| | Response is often result of exposure to pollutant | Exposure to pollutant is known to cause response in free-ranging organisms | Exposure to pollutant is known to cause response in controlled experiments | Response is practical to measure |
|---|---|---|---|---|
| Release of organ-specific enzymes | *No* | No | Yes | Yes |
| Reduced mammalian reproduction | No | Yes | Yes | No |
| ATP inhibition | No | No | Yes | Yes |
| Adrenal dysfunction | No | No | Yes | Yes |
| Gonadal dysfunction | No | No | Yes | Yes |
| Pituitary dysfunction | No | No | Yes | Yes |
| MFO inhibition | No | No | Yes | Yes |
| Alterations to carbohydrate, lipid and protein metabolism | No | No | Yes | Yes |
| Changes in DNA/RNA content or synthesis | No | No | Yes | Yes |
| Changes in basal metabolic rate | No | No | Yes | Yes |
| Impaired thermoregulation | No | No | Yes | Yes |
| Impaired intestinal transport | No | No | Yes | Yes |
| Impaired renal function | No | No | Yes | Yes |
| Clinical blood chemistry | No | No | Yes | Yes |
| Haematological alterations | No | No | Yes | Yes |

# Biomarkers & effects
# case studies, examples, summary

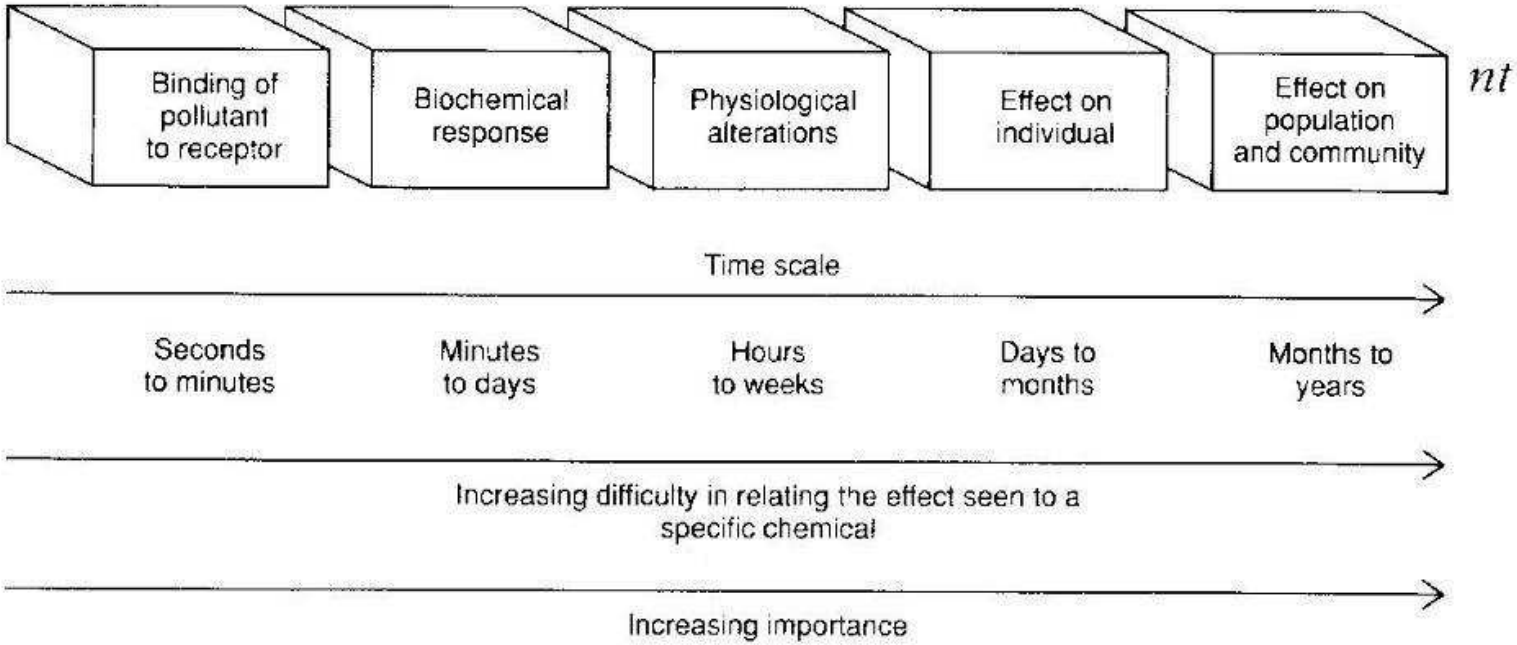



**Figure 10.5** Linkages between biochemical, physiological, individual and population responses to pollutants.

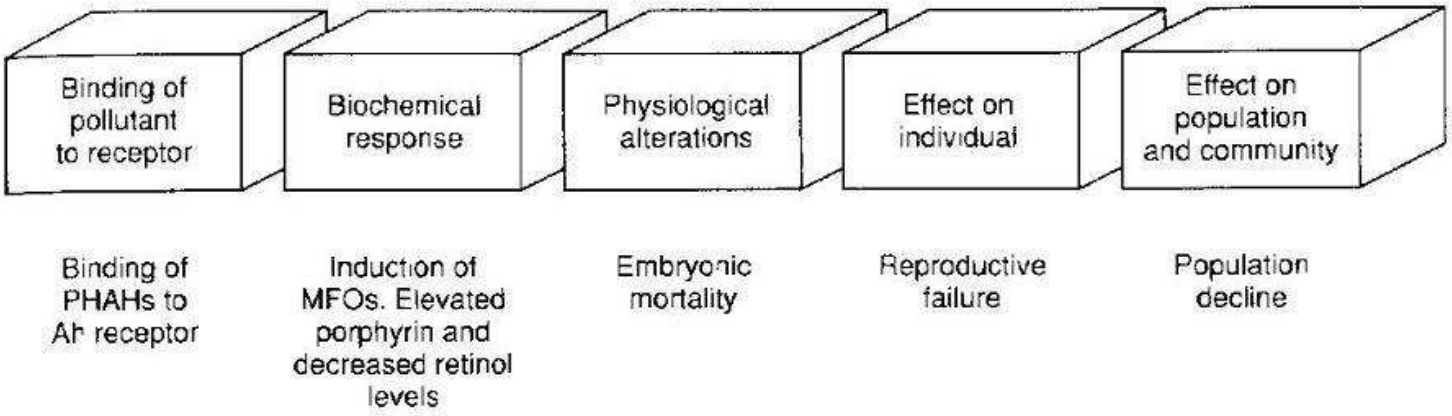



**Figure 10.6** Linkages in the reproductive failure of fish-eating birds and the Ah receptor.

# Pollutants & reproductive processes

**Table 3.2** Major pollutant-related effects on reproductive processes

| Species | Major findings | Biomarker studies |
|---|---|---|
| Mink | Complete reproductive failure of ranch mink fed Great Lakes fish (1). Population declines around the Great Lakes (2). Laboratory studies show sensitivity to PCBs and dioxins (3–5). | None carried out. Examination of reproductive impairment by dioxin equivalents should be made. |
| Seals | Decreased reproductive success and population declines in the Baltic and Wadden seas (6, 7) Experimental studies on Wadden Sea population suggest correlation with PCBs (8). | Marked changes in retinol and some changes in thyroid (9). Pathological changes in the Baltic population (10). |
| Raptoral birds | Decreased eggshell thickness leading to reproductive failure and widespread population declines (11, 12) Marked inter-species variation (13). | Caused by DDE (and closely related pesticide dicofol). Inhibition of Ca-ATPase (14) and effects on calmodulin (15). |
| Fish-eating birds | Decreased reproductive success, embryotoxic, behavioural effects and congenital abnormalities (2, 16, 17). | Good inverse relationship between reproductive success and dioxin equivalents based on AHH induction (18, 19). |
| Fish | Mortality of fry in hatcheries (20) and in field situations (21). Population effects seen in trout in New Brunswick and salmon in the Great Lakes (21, 22). | None carried out. |

# Regulation of reproduction

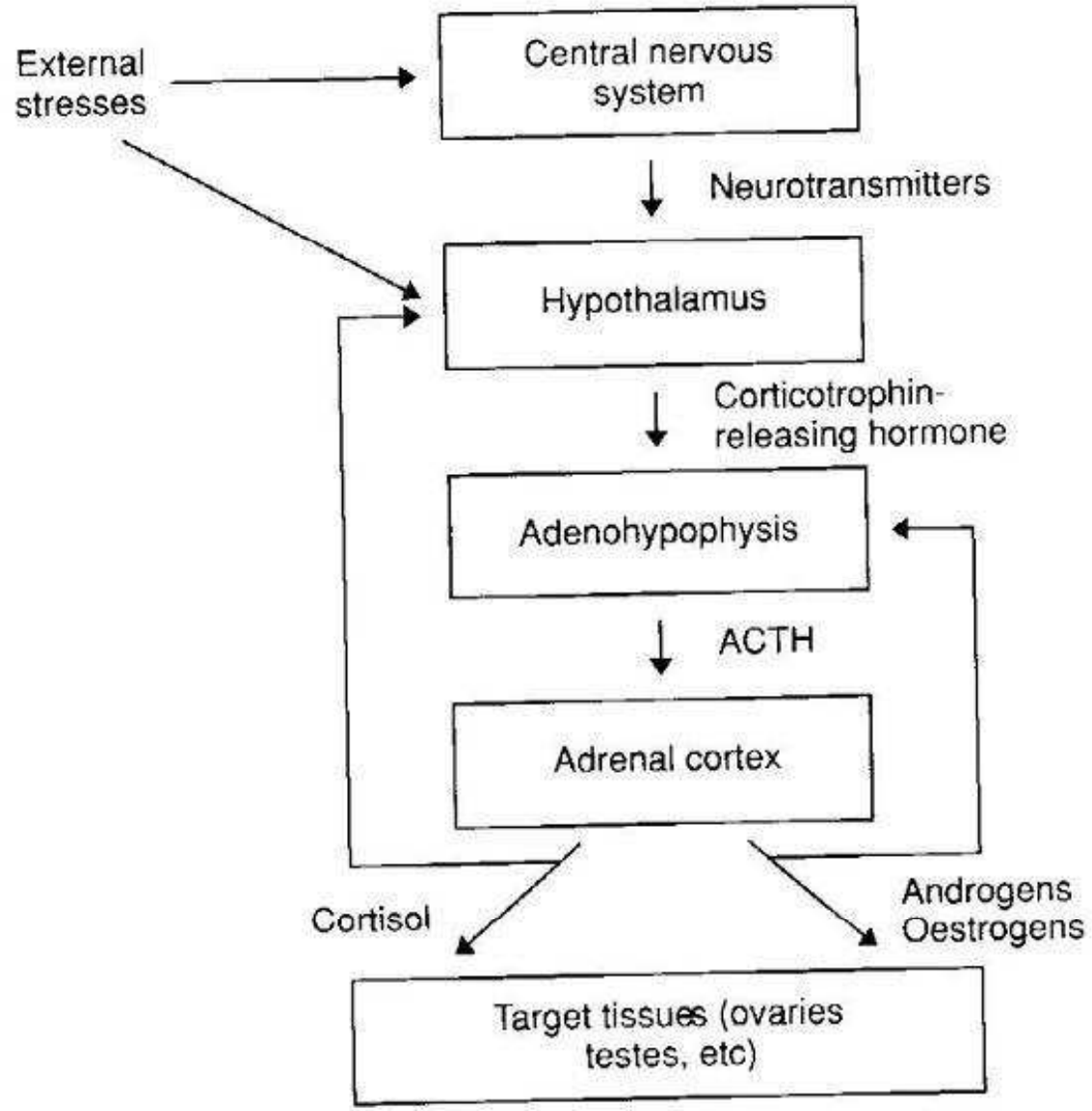



**Figure 3.3** Outline of hormonal control of reproduction.

# Regulation of reproduction

**Table 3.4** Effects of PCBs and DDE on reproductive behaviour, success and hormone levels in doves

| Chemical | Dose (ppm) | Courtship behaviour | Time to lay | Nest attendance | Reproductive success | LH | Steroid hormones | Reference |
|---|---|---|---|---|---|---|---|---|
| DDE | 10 | Decreased | – | – | – | – | – | (1) |
| | | – | ? | – | – | No effect | – | (2) |
| | 40 | – | – | – | Decreased | – | – | (3) |
| | | – | Increased | – | – | Fail to show surge | – | (2) |
| | 50 | Decreased | – | – | – | – | – | (1) |
| | 100 | Decreased | Increased | Decreased | Decreased | – | – | (4) |
| PCBs | 10 | – | Increased | Decreased | Decreased | – | – | (5) |
| | | | Increased | – | Decreased | – | Some changes | (6) |
| | 25 | Decreased | Increased | Decreased | Decreased | – | – | (7) |
| Mixture | Low | No effect | Increased | No effect | Decreased | – | Some changes | (8) |
| | High | Decreased | Increased | Decreased (brooding only) | Decreased | – | Some changes | (8) |

References: (1) Haegele and Hudson (1977); (2) Richie and Peterle (1979); (3) Haegele and Hudson (1973); (4) Keith (1978); (5) Peakall and Peakall (1973); (6) Koval *et al.* (1987); (7) Farve (1978); (8) McArthur *et al.* (1983).

# Retinoid metabolism & PCDDs

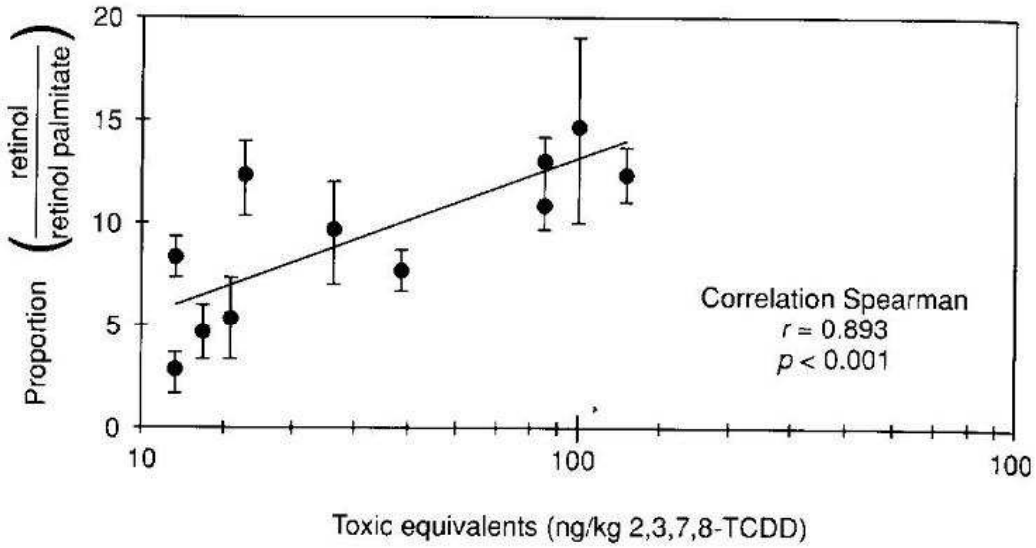



**Figure 6.6** Relationship of retinol and retinyl palmitate to dioxin equivalent. Spear (in press).

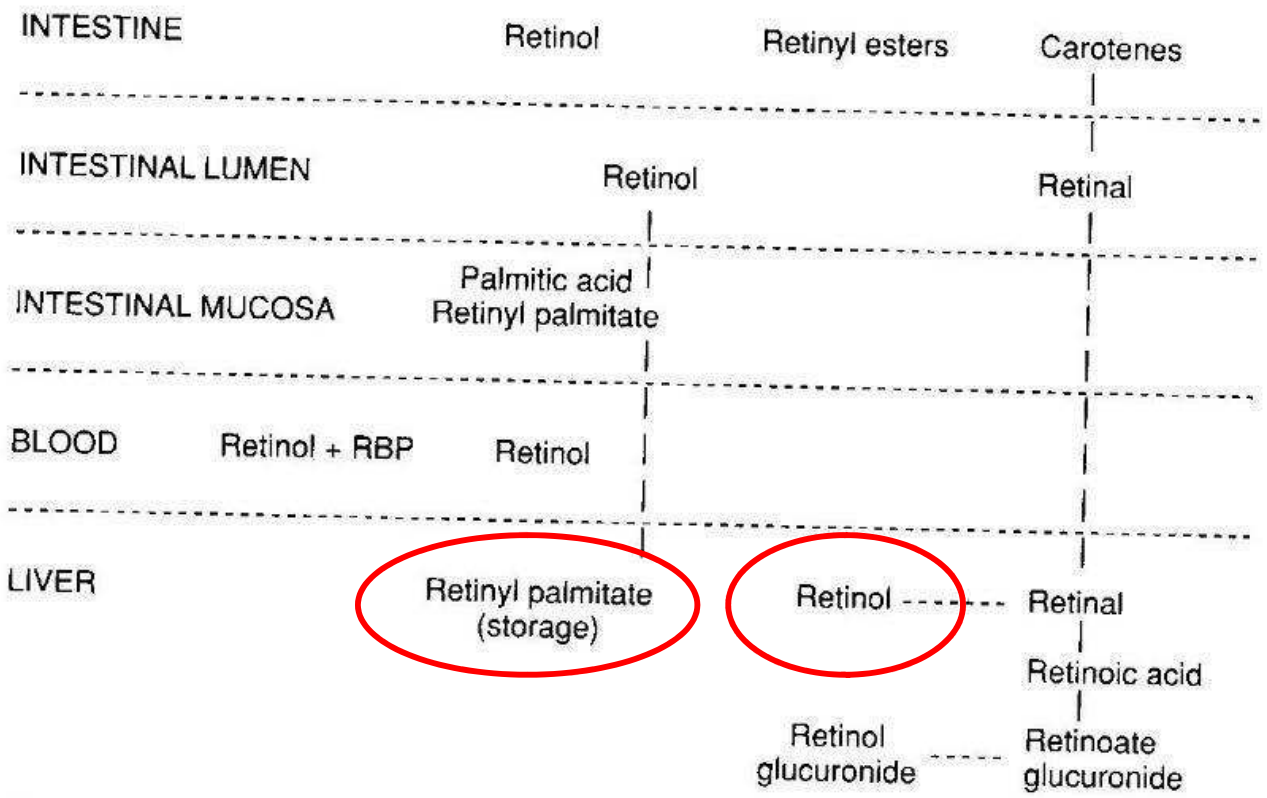



**Figure 6.4** Metabolic pathways of retinols.

# Variation of retinoid levels at different localities

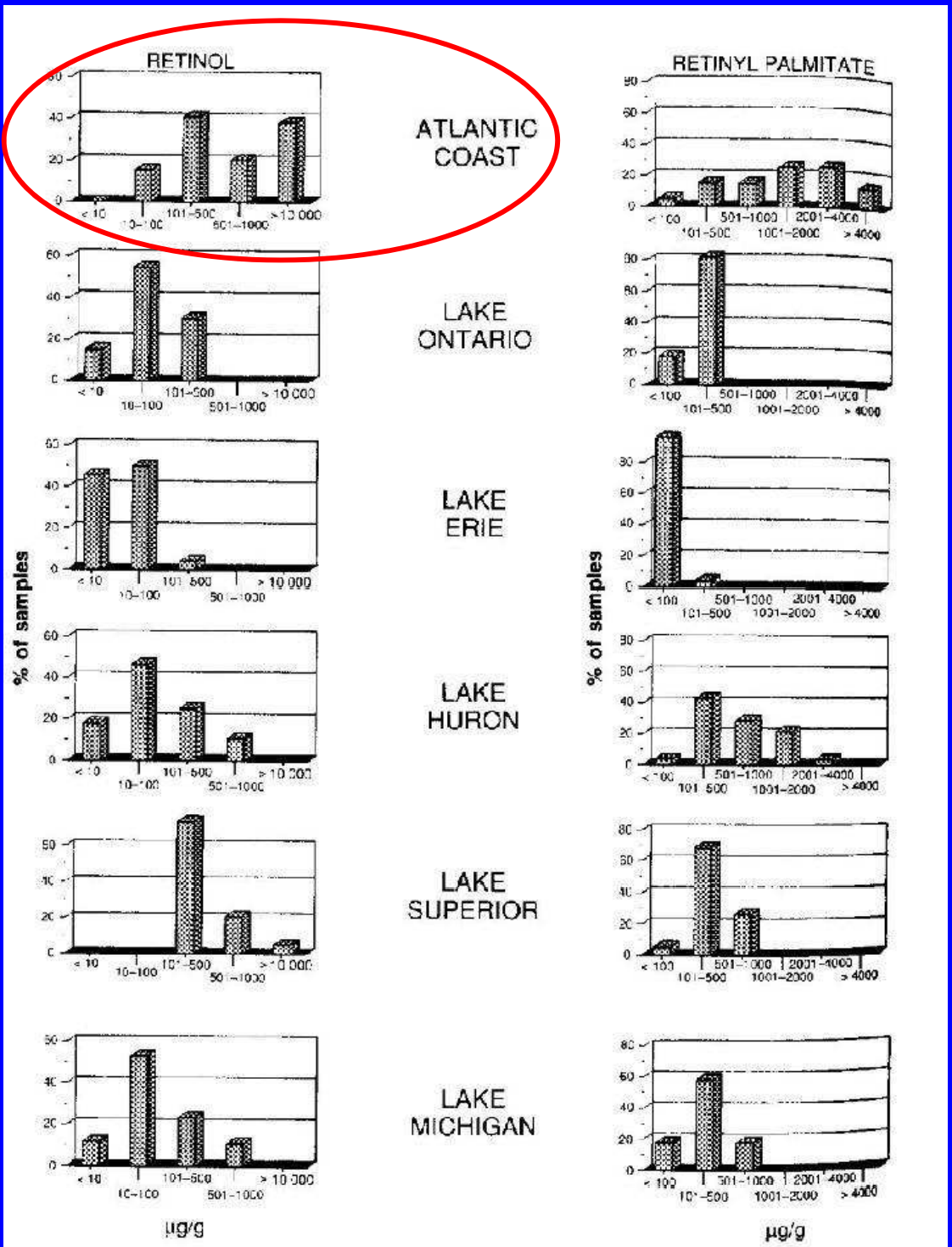



**Figure 6.5** Retinol and retinyl palmitate in livers of herring gulls. After Environment Canada (1991).

# Immunotoxicity of xenobiotics

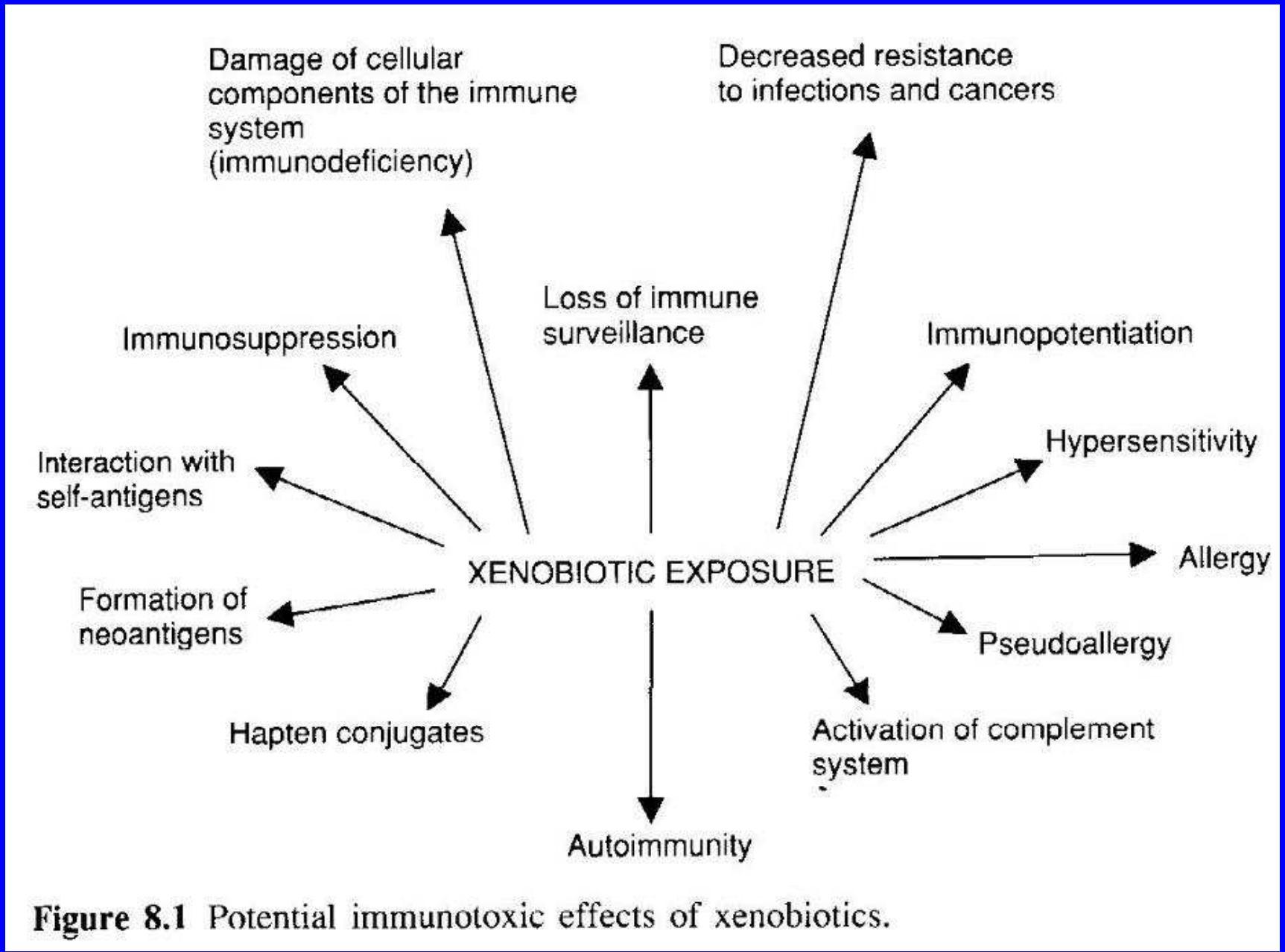



**Figure 8.1** Potential immunotoxic effects of xenobiotics.

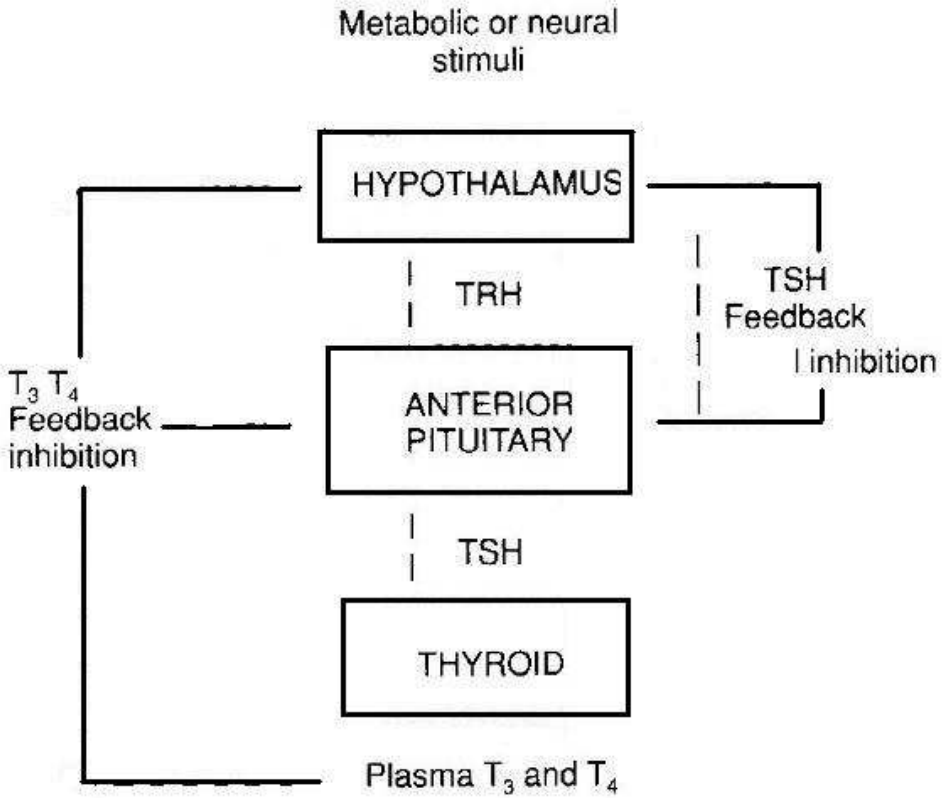
# Immunotoxicity of xenobiotics

**Table 8.2** Environmental chemicals that are considered potentially immunotoxic

| Chemical class | Immunotoxic effects* |
|---|---|
| Metals, organometals, metalloids | Suppression of HMI, CMI, NSR; induction of contact hypersensitivity; impairment of host resistance to infections and tumours |
| Halogenated hydrocarbons (aliphatic and aromatic), aromatic hydrocarbons | Suppression of HMI, CMI; impairment of host resistance to infections and tumours |
| Heterocyclic oxygen-containing compounds including epoxides, furans, dioxanes | Suppression of HMI, CMI; impairment of host resistance to infections and tumours |
| Carbamates | Modulation of CMI, HMI; modulation of host resistance to infections and tumours |
| Organophosphates | Suppression of HMI, CMI; impairment of host resistance to infections and tumours |

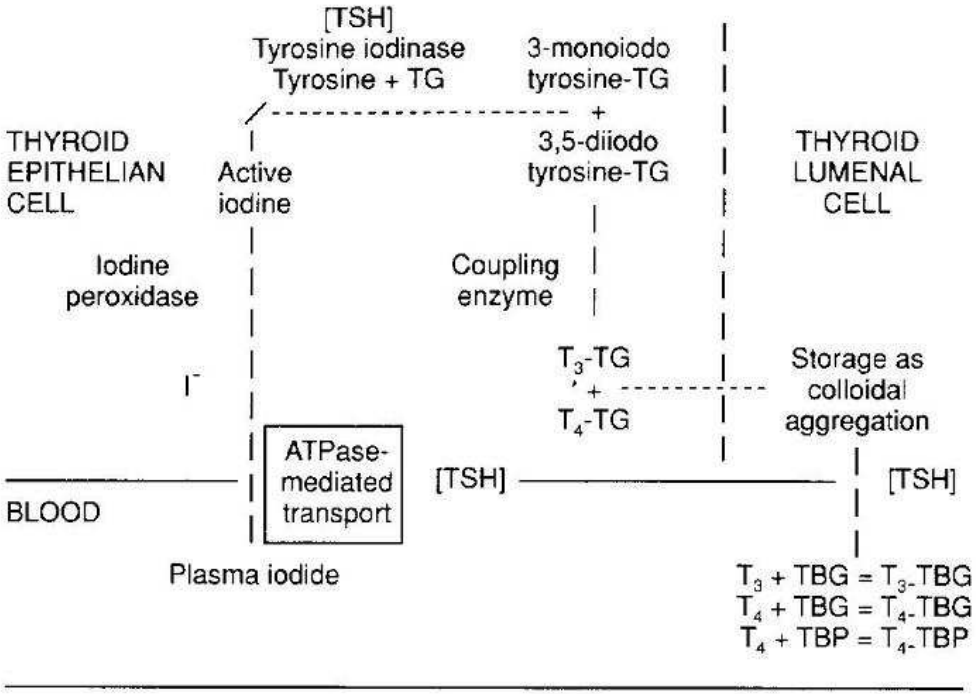
* Abbreviations: HMI: humoral-mediated immunity, CMI: cell-mediated immunity, NSR: nonspecific response.

# Xenobiotics and thyroid regulation




$T_3$ Triiodothyronine
$T_4$ Thyroxine
TRH Thyrotropin-releasing hormone
TSH Thyroid-stimulating hormone

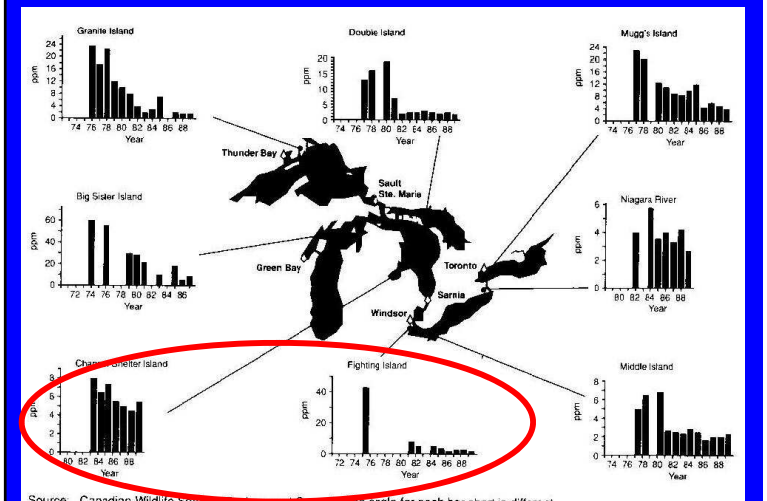
**Figure 6.1** Overall regulation of thyroid hormones.




$T_3$ Triiodothyronine
$T_4$ Thyroxine
TBG Thyroxine-binding globulin
TBP Thyroxine-binding prealbumin
TG Thyroglobulin
TSH Thyroid-stimulating hormone

**Figure 6.2** Metabolic pathways of the thyroid hormones.

# Xenobiotics and thyroid parameters




Source: Canadian Wildlife Service, Environment Canada. The scale for each bar chart is different.

**Figure 1.2** Temporal trends of DDE in Great Lakes herring gull eggs.

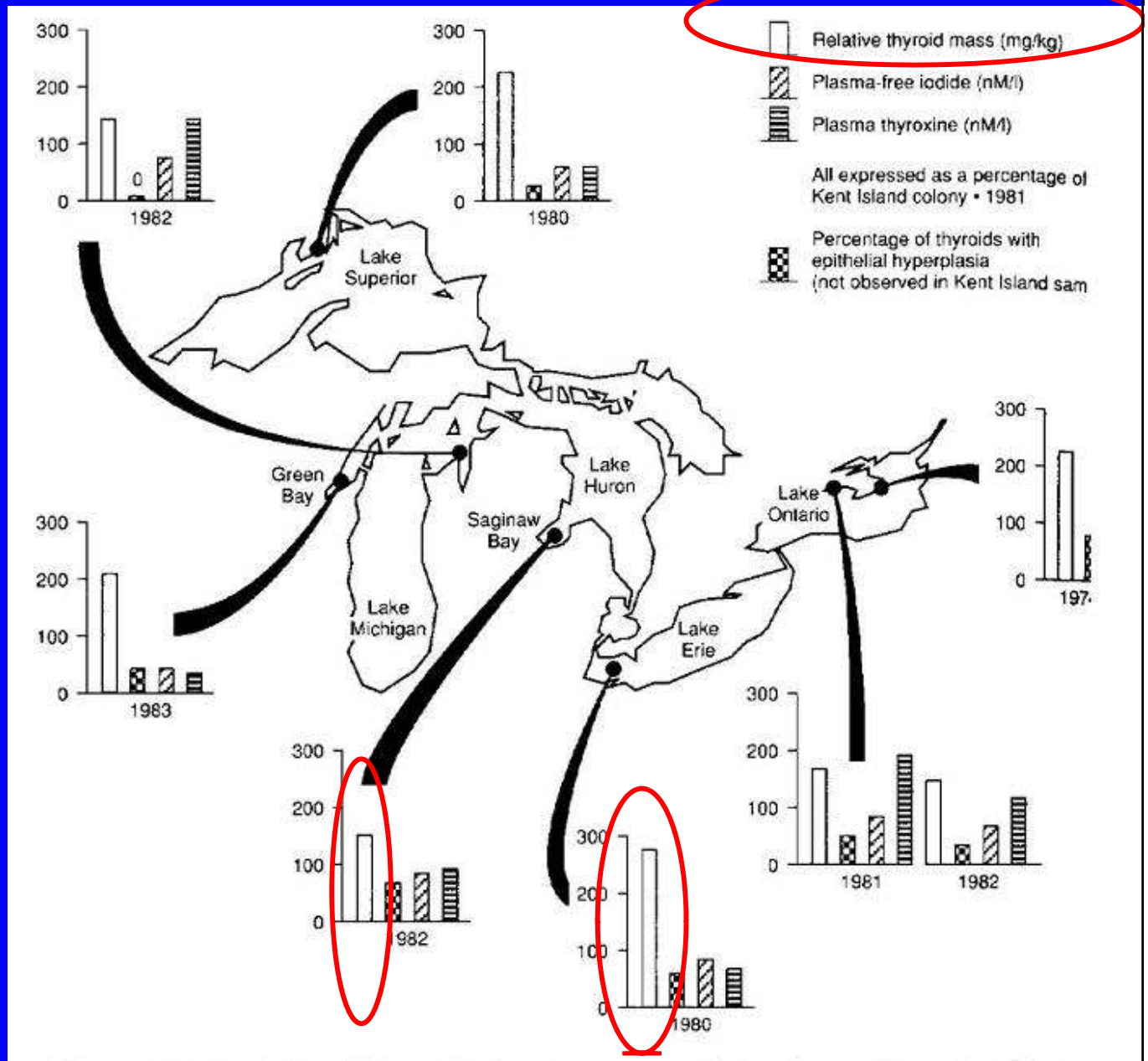



**Figure 6.3** Variation of thyroid-related parameters in herring gulls on the Great Lakes. G. Fox, Canadian Wildlife Service, Environment Canada (1991).

# Xenobiotics *(non-AcChE)* and neurotoxicity

Biomarkers = neurotransmitter levels

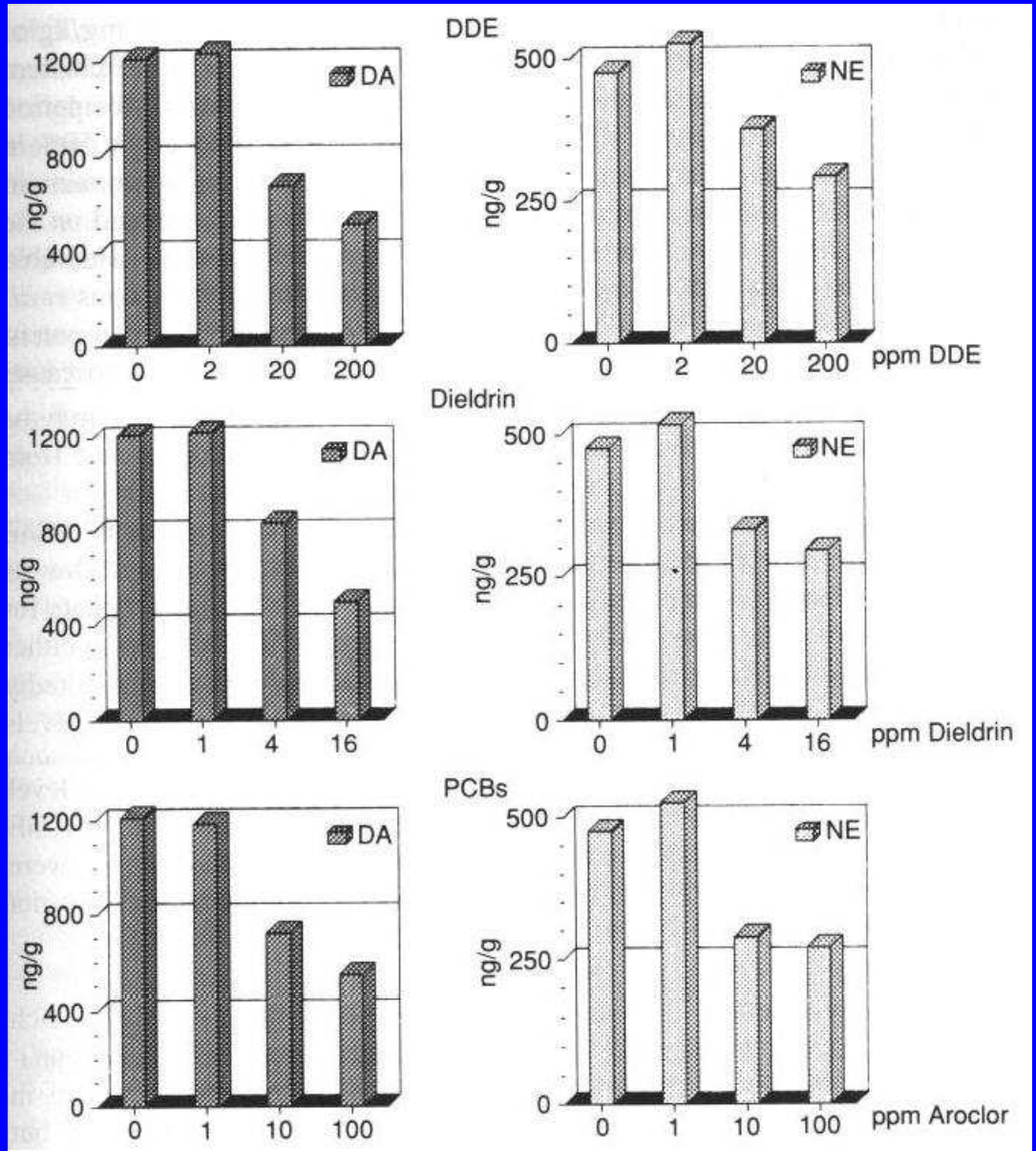



**Figure 2.11** Effect of DDE, dieldrin and PCBs on the levels of DA and NE in the brain of the ring-dove. After Heinz *et al.* (1980).