

# MODE OF ACTION CLASSIFICATION SCHEME

VERSION 10.4, DECEMBER 2022

PREPARED IRAC International MoA Working Group

APPROVED IRAC Executive



Insecticide Resistance Action Committee



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## Scope

The IRAC classification is intended to cover all materials, chemical, biological or other, that are used to control insects or acarines on crops, in structures or in the environment. Some insecticides and acaricides also control nematodes, but selective nematicides are covered in a separate Nematicide MoA classification document available at <https://www.irac-online.org/>. Behaviour-modifying agents and predatory insects/mites are not included. Products used only by direct application to animals or humans for control of parasites are likewise not included.

Note: Inclusion in the MoA list does not necessarily signify regulatory approval.

## Purpose

The IRAC Mode of Action (MoA) classification provides growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of acaricides or insecticides for use in an effective and sustainable acaricide or insecticide resistance management (IRM) strategy. In addition to presenting the MoA classification, this document outlines the background to, and purposes of, the classification list, and provides guidance on how it is used for IRM purposes. Many countries now require the IRAC MoA group code included on labels and this is recommended even if not required. Labeling guidelines are given in Appendix 1 and require that the active ingredient be listed in Appendix 5. Procedures for requesting IRAC classification of a new/unlisted active ingredient are found in Appendix 4. This document is reviewed and re-issued as needed.

## What is resistance?

Resistance to insecticides may be defined as '*a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species*' (IRAC). This definition differs slightly from others in the literature, but IRAC believes it represents the most accurate practical definition of relevance to growers. Resistance arises through the over-use or misuse of an insecticide or acaricide against a pest species and results from the Darwinian selection of resistant forms of the pest and the consequent evolution of populations that are resistant to that insecticide or acaricide.

# MoA, Target-site resistance and Cross-resistance

In many cases, not only does resistance render the selecting insecticidal or acaricidal agent ineffective, but it also confers cross-resistance to other structurally related agents. This is because agents with structural similarity usually share a common target site within the pest, and thus share a common MoA. It is common for resistance to develop that is based on a genetic modification of this target site. When this happens, the interaction of the selecting insecticidal or acaricidal agent with its target site is impaired and the agent loses its pesticidal efficacy. Because all insecticidal and acaricidal agents with structural similarity share a common MoA, there is a high risk that existing or developing target-site resistance will confer cross-resistance to all agents in the same group. It is this concept of cross-resistance within a family of structurally related insecticides or acaricides that is the basis of the IRAC MoA classification.

## Use of alternations or sequences of different MoAs

The objective of successful Insecticide Resistance Management (IRM) is to prevent or delay the evolution of resistance to insecticides, or to help regain susceptibility in insect pest populations in which resistance has already arisen. Effective IRM is thus an important element in maintaining the efficacy of valuable insecticides. It is important to recognize that it is usually easier to proactively prevent resistance from occurring than it is to reactively regain susceptibility. Nevertheless, the IRAC MoA classification will always provide valuable guidance to the design of effective IRM strategies.

Experience has shown that all effective insecticide or acaricide resistance management strategies seek to minimise the selection for resistance from any one type of insecticide or acaricide. In practice, alternations, sequences or rotations of insecticidal or acaricidal agents from different MoA groups provide a sustainable and effective approach to IRM. This ensures that selection from insecticidal agents in any one MoA group is minimised. The IRAC classification in this document is provided as an aid to insecticide selection for these types of IRM strategies. Applications are often arranged into MoA spray windows or blocks that are defined by the stage of crop development and the biology of the pest(s) of concern. Local expert advice should always be followed regarding spray windows and timings. Several sprays of an insecticidal agent may be possible within each spray window, but successive generations of a pest should not be treated with insecticidal agents from the same MoA group.

Groups in the classification whose members do not act at a common target site are exempt from the proscription against rotation within the group. These are Group 8, Miscellaneous non-specific (multi-site) inhibitors; Group 13, Uncouplers of oxidative phosphorylation via disruption of the proton gradient; and all the UN groups: UN, UNB, UNE, UNF, UNM, UNP and UNV.

To help delay resistance, it is strongly recommended that growers also integrate other control methods into insect or mite control programmes. Further advice is given in Appendix 2.

## Non-target-site resistance mechanisms

It is fully recognized that resistance of insects and mites to insecticides and acaricides can, and frequently does, result from enhanced metabolism by enzymes within the pest. Such metabolic resistance mechanisms are not linked to any specific site of action classification and therefore they may confer resistance to insecticides in more than one IRAC MoA group. Where such metabolic resistance has been characterized and the cross-resistance spectrum is known, it is possible that certain alternations, sequences or rotations of MoA groups cannot be used. Similarly, mechanisms of reduced penetration of the pesticide into the pest, or behavioural changes of the pest may also confer resistance to multiple MoA groups. Where such mechanisms are known to give cross-resistance between MoA groups, the use of insecticides should be modified appropriately.

Where the resistance mechanism(s) is unknown, the intelligent use of alternations, sequences or rotations of insecticidal agents from different MoA classes remains an entirely viable resistance management technique, since such a practice will always minimise selection pressures.

## The MoA Classification Scheme

The IRAC MoA classification scheme is based on the best available evidence of the MoA of available insecticidal and acaricidal agents. Details of the classification have been agreed upon by IRAC member companies and approved by internationally recognized industrial and academic insect toxicologists and biochemists.

Insecticidal and acaricidal agents are classified into two types of MoA groups: numbered groups whose members are known or thought to act at specific target sites, and UN groups of undefined or unknown mode of action. The only exceptions are the numbered groups 8, Miscellaneous non-specific (multi-site) inhibitors and 13, Uncouplers of oxidative phosphorylation via disruption of the proton gradient, which for historical reasons retain their legacy group numbers even though they are not acting at specific target sites. Nevertheless, it is the intention of the IRAC MoA working group going forward to only assign group numbers where there is good evidence of a common target site.

Insecticidal compounds, bacterial agents, extracts and crude oils, fungal agents, mechanical disruptors, peptides and viruses of unknown Mode of Action are classified in groups UN, UNB, UNE, UNF, UNM, UNP and UNV, respectively.

## Rules for inclusion of an insecticidal agent in the MoA list

- Chemical nomenclature is generally based on ISO accepted common names
- To be included in the active list, insecticidal agents must have a minimum of one registered use in at least one country.
- In any one MoA classification sub-group, where more than one active ingredient in that sub-group is registered for use, the sub-group name is used.
- In any one MoA classification sub-group, where only one active ingredient is registered for use, the name of that exemplifying active ingredient may be used

## The Classification Table

| IRAC MoA Classification Version 10.4, December 2022<br><i>See section 7.4 for further information on sub-groups.</i><br><i>See section 7.3 for criteria for descriptors of the quality of MoA information.</i> |                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Main Group and Primary Site of Action                                                                                                                                                                          | Sub-group, class or exemplifying Active Ingredient | Active Ingredients                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>1</b><br><b>Acetylcholinesterase (AChE) inhibitors</b><br><br>Nerve action<br><br>{Strong evidence that action at this protein is responsible for insecticidal effects}                                     | <b>1A</b><br>Carbamates                            | Alanycarb, Aldicarb, Bendiocarb, Benfuracarb, Butocarboxim, Butoxycarboxim, Carbaryl, Carbofuran, Carbosulfan, Ethiofencarb, Fenobucarb, Formetanate, Furathiocarb, Isoprocarb, Methiocarb, Methomyl, Metolcarb, Oxamyl, Pirimicarb, Propoxur, Thiodicarb, Thiofanox, Triazamate, Trimethacarb, XMC, Xylcarb                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                                                                                                                                                                                                                | <b>1B</b><br>Organophosphates                      | Acephate, Azamethiphos, Azinphos-ethyl, Azinphos-methyl, Cadusafos, Chlorethoxyfos, Chlorfenvinphos, Chlormephos, Chlorpyrifos, Chlorpyrifos-methyl, Coumaphos, Cyanophos, Demeton-S-methyl, Diazinon, Dichlorvos/ DDVP, Dicrotophos, Dimethoate, Dimethylvinphos, Disulfoton, EPN, Ethion, Ethoprophos, Famphur, Fenamiphos, Fenitrothion, Fenthion, Fosthiazate, Heptenophos, Imicyafos, Isofenphos, Isopropyl O-(methoxyaminothio-phosphoryl) salicylate, Isoxathion, Malathion, Mecarbam, Methamidophos, Methidathion, Mevinphos, Monocrotophos, Naled, Omethoate, Oxydemeton-methyl, Parathion, Parathion-methyl, Phenthoate, Phorate, Phosalone, Phosmet, Phosphamidon, Phoxim, Pirimiphos-methyl, Profenofos, Propetamphos, Prothiofos, Pyraclofos, Pyridaphenthion, Quinalphos, Sulfotep, Tebupirimfos, Temephos, Terbufos, Tetrachlorvinphos, Thiometon, Triazophos, Trichlorfon, Vamidothion |
| <b>2</b><br><b>GABA-gated chloride channel blockers</b><br><br>Nerve action<br><br>{Strong evidence that action at this protein is responsible for insecticidal effects}                                       | <b>2A</b><br>Cyclodiene<br>Organochlorines         | Chlordane, Endosulfan                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|                                                                                                                                                                                                                | <b>2B</b><br>Phenylpyrazoles<br>(Fiproles)         | Ethiprole, Fipronil                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

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*See section 7.4 for further information on sub-groups.  
See section 7.3 for criteria for descriptors of the quality of MoA information.*

| Main Group and Primary Site of Action                                                                                                                                                                                       | Sub-group, class or exemplifying Active Ingredient | Active Ingredients                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>3</b><br><b>Sodium channel modulators</b><br>Nerve action<br>{Strong evidence that action at this protein is responsible for insecticidal effects}                                                                       | <b>3A</b><br>Pyrethroids<br>Pyrethrins             | Acrinathrin, Allethrin, d- <i>cis-trans</i> Allethrin, d- <i>trans</i> Allethrin, Bifenthrin, Bioallethrin, Bioallethrin S-cyclopentenyl isomer, Bioresmethrin, Cycloprothrin, Cyfluthrin, <i>beta</i> -Cyfluthrin, Cyhalothrin, <i>lambda</i> -Cyhalothrin, <i>gamma</i> -Cyhalothrin, Cypermethrin, <i>alpha</i> -Cypermethrin, <i>beta</i> -Cypermethrin, <i>theta</i> -cypermethrin, <i>zeta</i> -Cypermethrin, Cyphenothrin, (1 <i>R</i> )- <i>trans</i> - isomers], Deltamethrin, Empenthrin (EZ)- (1 <i>R</i> )- isomers], Esfenvalerate, Etofenprox, Fenpropathrin, Fenvalerate, Flucythrinate, Flumethrin, <i>tau</i> -Fluvalinate, Halfenprox, Imiprothrin, Kadethrin, Permethrin, Phenothrin [(1 <i>R</i> )- <i>trans</i> - isomer], Prallethrin, Pyrethrins (pyrethrum), Resmethrin, Silafluofen, Tefluthrin, Tetramethrin, Tetramethrin [(1 <i>R</i> )-isomers], Tralomethrin, Transfluthrin, |
|                                                                                                                                                                                                                             | <b>3B</b><br>DDT<br>Methoxychlor                   | DDT<br>Methoxychlor                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>4</b><br><b>Nicotinic acetylcholine receptor (nAChR) competitive modulators</b><br>Nerve action<br>{Strong evidence that action at one or more of this class of protein is responsible for insecticidal effects}         | <b>4A</b><br>Neonicotinoids                        | Acetamiprid, Clothianidin, Dinotefuran, Imidacloprid, Nitenpyram, Thiacloprid, Thiamethoxam,                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|                                                                                                                                                                                                                             | <b>4B</b><br>Nicotine                              | Nicotine                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|                                                                                                                                                                                                                             | <b>4C</b><br>Sulfoximines                          | Sulfoxaflor                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                                                                                                                                                                                                                             | <b>4D</b><br>Butenolides                           | Flupyradifurone                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                                                                                                                                                                                                                             | <b>4E</b><br>Mesoionics                            | Triflumezopyrim                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                                                                                                                                                                                                                             | <b>4F</b><br>Pyridylidenes                         | Flupyrimin                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>5</b><br><b>Nicotinic acetylcholine receptor (nAChR) allosteric modulators – Site I</b><br>Nerve action<br>{Strong evidence that action at one or more of this class of protein is responsible for insecticidal effects} | Spinosyns                                          | Spinetoram, Spinosad                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

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See section 7.3 for criteria for descriptors of the quality of MoA information.*

| Main Group and Primary Site of Action                                                                                                                                                                                         | Sub-group, class or exemplifying Active Ingredient | Active Ingredients                                                       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|--------------------------------------------------------------------------|
| <b>6</b><br><b>Glutamate-gated chloride channel (GluCl) allosteric modulators</b><br>Nerve and muscle action<br>{Strong evidence that action at one or more of this class of protein is responsible for insecticidal effects} | Avermectins, Milbemycins                           | Abamectin, Emamectin benzoate, Lepimectin, Milbemectin                   |
| <b>7</b><br><b>Juvenile hormone mimics</b><br>Growth regulation<br>{Target protein responsible for biological activity is unknown, or uncharacterized}                                                                        | <b>7A</b><br>Juvenile hormone analogues            | Hydroprene, Kinoprene, Methoprene                                        |
|                                                                                                                                                                                                                               | <b>7B</b><br>Fenoxycarb                            | Fenoxycarb                                                               |
|                                                                                                                                                                                                                               | <b>7C</b><br>Pyriproxyfen                          | Pyriproxyfen                                                             |
| <b>8 *</b><br><b>Miscellaneous non-specific (multi-site) inhibitors</b>                                                                                                                                                       | <b>8A</b><br>Alkyl halides                         | Methyl bromide and other alkyl halides                                   |
|                                                                                                                                                                                                                               | <b>8B</b><br>Chloropicrin                          | Chloropicrin                                                             |
|                                                                                                                                                                                                                               | <b>8C</b><br>Fluorides                             | Cryolite (Sodium aluminum fluoride), Sulfuryl fluoride                   |
|                                                                                                                                                                                                                               | <b>8D</b><br>Borates                               | Borax, Boric acid, Disodium octaborate, Sodium borate, Sodium metaborate |
|                                                                                                                                                                                                                               | <b>8E</b><br>Tartar emetic                         | Tartar emetic                                                            |
|                                                                                                                                                                                                                               | <b>8F</b><br>Methyl isothiocyanate generators      | Dazomet, Metam                                                           |
| <b>9</b><br><b>Chordotonal organ TRPV channel modulators</b><br>Nerve action<br>{Strong evidence that action at one or more of this class of proteins is responsible for insecticidal effects}                                | <b>9B</b><br>Pyridine azomethine derivatives       | Pymetrozine, Pyriproxyfen                                                |
|                                                                                                                                                                                                                               | <b>9D</b><br>Pyropenes                             | Afidopyropen                                                             |

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| Main Group and Primary Site of Action                                                                                                                                                                                                                                   | Sub-group, class or exemplifying Active Ingredient                                     | Active Ingredients                                                                                                                                                                                                                                                                                                                                                                         |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>10</b><br><b>Mite growth inhibitors affecting CHS1</b><br>Growth regulation<br>{Strong evidence that action at one or more of this class of proteins is responsible for insecticidal effects}                                                                        | <b>10A</b><br>Clofentezine<br>Diflovidazin<br>Hexythiazox                              | Clofentezine, Diflovidazin, Hexythiazox                                                                                                                                                                                                                                                                                                                                                    |
|                                                                                                                                                                                                                                                                         | <b>10B</b><br>Etoxazole                                                                | Ettoxazole                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>11</b><br><b>Microbial disruptors of insect midgut membranes</b><br>(Includes transgenic crops expressing <i>Bacillus thuringiensis</i> toxins, however specific guidance for resistance management of transgenic crops is not based on rotation of modes of action) | <b>11A</b><br><i>Bacillus thuringiensis</i> and the insecticidal proteins they produce | <i>Bacillus thuringiensis</i> subsp. <i>israelensis</i><br><i>Bacillus thuringiensis</i> subsp. <i>aizawai</i><br><i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i><br><i>Bacillus thuringiensis</i> subsp. <i>tenebrionis</i><br><br><i>B.t.</i> crop proteins: (* Please see footnote)<br>Cry1Ab, Cry1Ac, Cry1Fa, Cry1A.105, Cry2Ab, Vip3A, mCry3A, Cry3Ab, Cry3Bb, Cry34Ab1/Cry35Ab1 |
|                                                                                                                                                                                                                                                                         | <b>11B</b><br><i>Bacillus sphaericus</i>                                               | <i>Bacillus sphaericus</i>                                                                                                                                                                                                                                                                                                                                                                 |
| <b>12</b><br><b>Inhibitors of mitochondrial ATP synthase</b><br>Energy metabolism<br>{Compounds affect the function of this protein, but it is not clear that this is what leads to biological activity}                                                                | <b>12A</b><br>Diafenthion                                                              | Diafenthion                                                                                                                                                                                                                                                                                                                                                                                |
|                                                                                                                                                                                                                                                                         | <b>12B</b><br>Organotin miticides                                                      | Azocyclotin, Cyhexatin, Fenbutatin oxide                                                                                                                                                                                                                                                                                                                                                   |
|                                                                                                                                                                                                                                                                         | <b>12C</b><br>Propargite                                                               | Propargite                                                                                                                                                                                                                                                                                                                                                                                 |
|                                                                                                                                                                                                                                                                         | <b>12D</b><br>Tetradifon                                                               | Tetradifon                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>13 *</b><br><b>Uncouplers of oxidative phosphorylation via disruption of the proton gradient</b><br>Energy metabolism                                                                                                                                                | Pyrroles<br><br>Dinitrophenols<br><br>Sulfluramid                                      | Chlorfenapyr<br><br>DNOC<br><br>Sulfluramid                                                                                                                                                                                                                                                                                                                                                |

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See section 7.3 for criteria for descriptors of the quality of MoA information.

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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>14</b><br><b>Nicotinic acetylcholine receptor (nAChR) channel blockers</b><br>Nerve action<br>{Compounds affect the function of this protein, but it is not clear that this is what leads to biological activity} | Nereistoxin analogues                              | Bensultap, Cartap hydrochloride, Thiocyclam, Thiosultap-sodium                                                                                         |
| <b>15</b><br><b>Inhibitors of chitin biosynthesis affecting CHS1</b><br>Growth regulation<br>{Strong evidence that action at one or more of this class of proteins is responsible for insecticidal effects}          | Benzoylureas                                       | Bistrifluron, Chlorfluazuron, Diflubenzuron, Flucycloxuron, Flufenoxuron, Hexaflumuron, Lufenuron, Novaluron, Noviflumuron, Teflubenzuron, Triflumuron |
| <b>16</b><br><b>Inhibitors of chitin biosynthesis, type 1</b><br>Growth regulation<br>{Target protein responsible for biological activity is unknown, or uncharacterized}                                            | Buprofezin                                         | Buprofezin                                                                                                                                             |
| <b>17</b><br><b>Moulting disruptors, Dipteran</b><br>Growth regulation<br>{Target protein responsible for biological activity is unknown, or uncharacterized}                                                        | Cyromazine                                         | Cyromazine                                                                                                                                             |
| <b>18</b><br><b>Ecdysone receptor agonists</b><br>Growth regulation<br>{Strong evidence that action at this protein is responsible for insecticidal effects}                                                         | Diacylhydrazines                                   | Chromafenozide, Halofenozide, Methoxyfenozide, Tebufenozide                                                                                            |

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| Main Group and Primary Site of Action                                                                                                                                                                     | Sub-group, class or exemplifying Active Ingredient | Active Ingredients                                                           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|------------------------------------------------------------------------------|
| <b>19</b><br><b>Octopamine receptor agonists</b><br>Nerve action<br>{Good evidence that action at one or more of this class of protein is responsible for insecticidal effects}                           | Amitraz                                            | Amitraz                                                                      |
| <b>20</b><br><b>Mitochondrial complex III electron transport inhibitors – Qo site</b><br>Energy metabolism<br>{Good evidence that action at this protein complex is responsible for insecticidal effects} | <b>20A</b><br>Hydramethylnon                       | Hydramethylnon                                                               |
|                                                                                                                                                                                                           | <b>20B</b><br>Acequinocyl                          | Acequinocyl                                                                  |
|                                                                                                                                                                                                           | <b>20C</b><br>Fluacrypyrim                         | Fluacrypyrim                                                                 |
|                                                                                                                                                                                                           | <b>20D</b><br>Bifenazate                           | Bifenazate                                                                   |
| <b>21</b><br><b>Mitochondrial complex I electron transport inhibitors</b><br>Energy metabolism<br>{Good evidence that action at this protein complex is responsible for insecticidal effects}             | <b>21A</b><br>METI acaricides and insecticides     | Fenazaquin, Fenpyroximate, Pyridaben, Pyrimidifen, Tebufenpyrad, Tolfenpyrad |
|                                                                                                                                                                                                           | <b>21B</b><br>Rotenone                             | Rotenone (Derris)                                                            |
| <b>22</b><br><b>Voltage-dependent sodium channel blockers</b><br>Nerve action<br>{Good evidence that action at this protein complex is responsible for insecticidal effects}                              | <b>22A</b><br>Oxadiazines                          | Indoxacarb                                                                   |
|                                                                                                                                                                                                           | <b>22B</b><br>Semicarbazones                       | Metaflumizone                                                                |

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| Main Group and Primary Site of Action                                                                                                                                                          | Sub-group, class or exemplifying Active Ingredient | Active Ingredients                                                                  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|-------------------------------------------------------------------------------------|
| <b>23</b><br><b>Inhibitors of acetyl CoA carboxylase</b><br>Lipid synthesis, growth regulation<br>{Good evidence that action at this protein is responsible for insecticidal effects}          | Tetronic and Tetramic acid derivatives             | Spirodiclofen, Spiromesifen, Spiropidion, Spirotetramat                             |
| <b>24</b><br><b>Mitochondrial complex IV electron transport inhibitors</b><br>Energy metabolism<br>{Good evidence that action at this protein complex is responsible for insecticidal effects} | <b>24A</b><br>Phosphides                           | Aluminium phosphide, Calcium phosphide, Phosphine, Zinc phosphide                   |
|                                                                                                                                                                                                | <b>24B</b><br>Cyanides                             | Calcium cyanide, Potassium cyanide, Sodium cyanide                                  |
| <b>25</b><br><b>Mitochondrial complex II electron transport inhibitors</b><br>Energy metabolism<br>{Good evidence that action at this protein complex is responsible for insecticidal effects} | <b>25A</b><br><i>Beta</i> -ketonitrile derivatives | Cyenopyrafen, Cyflumetofen                                                          |
|                                                                                                                                                                                                | <b>25B</b><br>Carboxanilides                       | Pyflubumide                                                                         |
| <b>28</b><br><b>Ryanodine receptor modulators</b><br>Nerve and muscle action<br>{Strong evidence that action at this protein complex is responsible for insecticidal effects}                  | Diamides                                           | Chlorantraniliprole, Cyantraniliprole, Cyclaniliprole Flubendiamide, Tetraniliprole |

## IRAC MoA Classification Version 10.4, December 2022

*See section 7.4 for further information on sub-groups.  
See section 7.3 for criteria for descriptors of the quality of MoA information.*

| Main Group and Primary Site of Action                                                                                                                                                                                                                                                       | Sub-group, class or exemplifying Active Ingredient        | Active Ingredients                                                                                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| <b>29</b><br><b>Chordotonal organ modulators - undefined target site</b><br>Nerve action<br>(Modulation of chordotonal organ function has been clearly demonstrated, but the specific target protein(s) responsible for biological activity are distinct from Group 9 and remain undefined) | Flonicamid                                                | Flonicamid                                                                                                                                  |
| <b>30</b><br><b>GABA-gated chloride channel allosteric modulators</b><br>Nerve action<br>{Strong evidence that action at this protein complex is responsible for insecticidal effects}                                                                                                      | Meta-diamides<br>Isoxazolines                             | Broflanilide<br>Fluxametamide, Isocyloseram                                                                                                 |
| <b>31</b><br><b>Baculoviruses</b><br>Host-specific occluded pathogenic viruses<br>(Midgut epithelial columnar cell membrane target site – undefined)                                                                                                                                        | Granuloviruses (GVs)<br><br>Nucleopolyhedroviruses (NPVs) | <i>Cydia pomonella</i> GV<br><i>Thaumetotibia leucotreta</i> GV<br><br><i>Anticarsia gemmatilis</i> MNPV<br><i>Helicoverpa armigera</i> NPV |
| <b>32</b><br><b>Nicotinic Acetylcholine Receptor (nAChR) Allosteric Modulators - Site II</b><br>Nerve action<br>{Strong evidence that action at one or more of this class of protein is responsible for insecticidal effects}                                                               | GS-omega/kappa HXTX-Hv1a peptide                          | GS-omega/kappa HXTX-Hv1a peptide                                                                                                            |

## IRAC MoA Classification Version 10.4, December 2022

See section 7.4 for further information on sub-groups.  
See section 7.3 for criteria for descriptors of the quality of MoA information.

| Main Group and Primary Site of Action                                                                                                                                                                                                                                           | Sub-group, class or exemplifying Active Ingredient | Active Ingredients                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|-------------------------------------------------------------|
| <b>33</b><br><b>Calcium-activated potassium channel (KCa2) modulators</b><br><br>Nerve action<br>{Strong evidence that action at this protein is responsible for insecticidal effects}                                                                                          | Acynonapyr                                         | Acynonapyr                                                  |
| <b>34</b><br><b>Mitochondrial complex III electron transport inhibitors – Qi site</b><br><br>Energy metabolism<br>{Modulation of this protein complex has been clearly demonstrated and the specific target site responsible for biological activity is distinct from Group 20} | Flometoquin                                        | Flometoquin                                                 |
| <b>UN*</b><br><b>Compounds of unknown or uncertain MoA</b><br>{Target protein responsible for biological activity is unknown, or uncharacterized}                                                                                                                               | Azadirachtin                                       | Azadirachtin                                                |
|                                                                                                                                                                                                                                                                                 | Benzoximate                                        | Benzoximate                                                 |
|                                                                                                                                                                                                                                                                                 | Benzpyrimoxan                                      | Benzpyrimoxan                                               |
|                                                                                                                                                                                                                                                                                 | Bromopropylate                                     | Bromopropylate                                              |
|                                                                                                                                                                                                                                                                                 | Chinomethionat                                     | Chinomethionat                                              |
|                                                                                                                                                                                                                                                                                 | Dicofol                                            | Dicofol                                                     |
|                                                                                                                                                                                                                                                                                 | Lime sulfur                                        | Lime sulfur                                                 |
|                                                                                                                                                                                                                                                                                 | Mancozeb                                           | Mancozeb                                                    |
|                                                                                                                                                                                                                                                                                 | Oxazosulfyl                                        | Oxazosulfyl                                                 |
|                                                                                                                                                                                                                                                                                 | Pyridalyl                                          | Pyridalyl                                                   |
|                                                                                                                                                                                                                                                                                 | Sulfur                                             | Sulfur                                                      |
| <b>UNB*</b><br><b>Bacterial agents (non-Bt) of unknown or uncertain MoA</b><br>{Target protein responsible for biological activity is unknown or uncharacterized}                                                                                                               |                                                    | <i>Burkholderia</i> spp<br><i>Wolbachia pipientis</i> (Zap) |

## IRAC MoA Classification Version 10.4, December 2022

See section 7.4 for further information on sub-groups.  
See section 7.3 for criteria for descriptors of the quality of MoA information.

| Main Group and Primary Site of Action                                                                                                                                                                         | Sub-group, class or exemplifying Active Ingredient | Active Ingredients                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNE*</b><br><b>Botanical essence including synthetic, extracts and unrefined oils with unknown or uncertain MoA</b><br>{Target protein responsible for biological activity is unknown, or uncharacterized} |                                                    | <i>Chenopodium ambrosioides</i> near <i>ambrosioides</i> extract<br>Fatty acid monoesters with glycerol or propanediol<br>Neem oil |
| <b>UNF*</b><br><b>Fungal agents of unknown or uncertain MoA</b><br>{Target protein responsible for biological activity is unknown, or uncharacterized}                                                        |                                                    | <i>Beauveria bassiana</i> strains<br><i>Metarhizium brunneum</i> strain F52<br><i>Paecilomyces fumosoroseus</i> Apopka strain 97   |
| <b>UNM*</b><br><b>Non-specific mechanical and physical disruptors</b><br>{Target protein responsible for biological activity is unknown, or uncharacterized}                                                  |                                                    | Diatomaceous earth<br>Mineral oil                                                                                                  |
| <b>UNP*</b><br><b>Peptides of unknown or uncertain MoA</b><br>{Target protein responsible for biological activity is unknown, or uncharacterized}                                                             |                                                    |                                                                                                                                    |
| <b>UNV*</b><br><b>Viral agents (non-baculovirus) of unknown or uncertain MoA</b><br>{Target protein responsible for biological activity is unknown, or uncharacterized}                                       |                                                    |                                                                                                                                    |

Targeted Physiology: ■ Nerve & Muscle ■ Growth & Development ■ Respiration ■ Midgut ■ Unknown or Non-Specific

## Table Notes:

- a) The color scheme used here associates modes of action into broad categories based on the physiological functions affected, as an aid to understanding symptomology, speed of action and other properties of the insecticides, and not for any resistance management purpose. **Rotations for resistance management should be based only on the numbered mode of action groups.**
- b) Inclusion of an insecticidal agent in the classification above does not necessarily signify regulatory approval.
- c) MoA assignments will usually involve identification of the target protein responsible for the biological effect, although groupings can be made where insecticidal agents share distinctive physiological effects and are structurally related.
- d) Groups 26 and 27 are unassigned at this time and have therefore been omitted from the table.
- e) An insecticidal agent with an unknown or controversial MoA or an unknown mode of toxicity will be held in group 'UN' or 'UNB', 'UNE', 'UNF', 'UNM', 'UNP', UNV as applicable until evidence becomes available to enable assignment to a more appropriate MoA class.
- f) Actives in groups marked with an asterisk are thought not to share a common target site and therefore may be freely rotated with each other unless there is reason to expect cross-resistance. These groups are 8, 13, UN, UNB, UNE, UNF, UNM, UNP and UNV.
- g) Different baculoviruses that target different insect orders may be used together without compromising their resistance management. Rotation between certain specific baculoviruses may provide resistance management benefits for some pests. Consult product-specific recommendations.
- h) While there is strong evidence that Bifenazate acts on the Qo site of Mitochondrial Complex III and some Bifenazate resistance mutations confer cross-resistance to acequinocyl, the sites of action of Fluacrypyrim and Hydramethylnon have not been determined.

## Criteria for descriptors of the quality of MoA information

|                                                                                                                               |                                                                                                                                                                                                                                                                                                                |
|-------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| {Strong evidence that action at this protein (or protein complex) is responsible for insecticidal effects}                    | Potent effects on the function of the target protein <u>and</u> either resistance due to mutation / overexpression / removal of this protein <u>or</u> correlation of potency between effects on the protein and biological activity for a set of related insecticidal agents.                                 |
| {Good evidence that action at this protein (or protein complex) is responsible for insecticidal effects}                      | Highly potent effects on the function of the protein combined with clearly consistent physiological effects                                                                                                                                                                                                    |
| {Insecticidal agents affect the function of this protein, but it is not clear that this is what leads to biological activity} | Insecticidal agents (or their active principles) have moderate or low potency on the function of the protein, and there is little or no evidence associating this effect with biological activity. Insecticidal agents may be grouped because of similarity of structure and distinctive physiological effect. |
| {Target protein responsible for biological activity is unknown, or uncharacterized}                                           | Insecticidal agents may be grouped because of similarity of structure and distinctive physiological effect.                                                                                                                                                                                                    |

## Notes regarding sub-groups

Sub-groups represent distinct classes of insecticidal agents that are believed to have the same MoA but are different enough in structure or mode of interaction with the target protein that the chance of selection for either metabolic or target-site cross-resistance is reduced compared to closely related insecticidal agents. Sub-groups may also distinguish insecticidal agents that are structurally similar but known to bind differently within the target or to have differential selectivity among multiple targets. Evidence supporting lack of cross-resistance between existing compounds within the Group and the new active ingredient submission must be provided to support sub-grouping. This should include bioassay-based studies and provide quantifiable resistance ratios between susceptible and resistant strains.

The cross-resistance potential between sub-groups is higher than that between different groups, so rotation between sub-groups should be avoided. In exceptional circumstances (i.e. where effective registered insecticides from other mode of action groups are unavailable) rotation may be considered following consultation with local expert advice and where cross-resistance does not exist. These exceptions should not be considered sustainable resistance management strategies, and alternative options should be sought to maintain pest susceptibility.

The following notes provide additional information about particular sub-groups.

| Sub-groups              | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3A & 3B                 | Because DDT is no longer used in agriculture, this is only applicable for the control of insect vectors of human disease such as mosquitoes.                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 4A, 4B, 4C, 4D, 4E & 4F | Although these compounds are believed to have the same target site, current evidence indicates that the risk of metabolic cross-resistance between subgroups is low.                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 10A                     | Hexythiazox is grouped with clofentezine because they exhibit cross-resistance, even though they are structurally distinct. Diflovidazin has been added to this group because it is a close analogue of clofentezine and is expected to have the same mode of action.                                                                                                                                                                                                                                                                                                                            |
| 11A                     | Different <i>Bacillus thuringiensis</i> products that target different insect orders may be used together without compromising their resistance management. Rotation between certain specific <i>Bacillus thuringiensis</i> microbial products may provide resistance management benefits for some pests. Consult product-specific recommendations.<br><u>B.t. Crop Proteins:</u> Where there are differences among the specific receptors within the midguts of target insects, transgenic crops containing certain combinations of the listed proteins provide resistance management benefits. |
| 22A & 22B               | Although these compounds are believed to have the same target site, current evidence indicates that the risk of metabolic cross-resistance between subgroups is low.                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 25A & 25B               | Although these compounds are believed to have the same target site, current evidence indicates that the risk of metabolic cross-resistance between subgroups is low.                                                                                                                                                                                                                                                                                                                                                                                                                             |

## General notes & MoA Classification Scheme updates

- Further details on the MoA Group Descriptors are given in Appendix 3.
- A list of active ingredients in alphabetical order with their respective MoA classification is given in Appendix 5.
- The Classification Scheme has been prepared using the most up-to-date information available to IRAC. It is provided to user groups, grower organisations, extension personnel, regulatory authorities such as the US EPA and all those involved in resistance management, as an agreed definitive statement by the plant protection industry on the MoA of insecticides currently in use.
- The IRAC MoA classification is reviewed and reissued at intervals as required. The latest version is always available for reference via the IRAC website ([www.irac-online.org](http://www.irac-online.org)).
- Submissions for new active ingredients together with recommendations for their inclusion in specific new or existing MoA classes, together with citations or evidence for classification should be made to IRAC through the website.
- IRAC member companies review draft versions before an agreed final version of any update is published. In addition, several internationally well-known insect toxicologists and biochemists can be consulted regarding additions, deletions or other changes to the list. Details of the procedures followed for allocation of new insecticidal materials to the MoA classification are given in Appendix 4.
- Changes to the listing may have serious consequences. In those countries where insecticide labels display the IRAC MoA number or class name as an aid to good IRM (see Appendix 1), changes may be especially costly to implement. In general, changes are therefore only endorsed when the scientific evidence supporting the change is compelling.
- Superseded, obsolete or withdrawn insecticidal agents for which no current registration exists, and that are no longer in common usage, are not listed.
- In a continued effort to refine the list, readers are kindly asked to inform IRAC of factual errors or omissions, citing definitive evidence wherever possible. Such submissions should be directed to IRAC via the website. Suggestions for improvements are likewise welcome.

# Appendix 1

## Product labels: Indication of MoA of active ingredient and accompanying IRM advice

To assist users in the selection of insecticides for use in IRM strategies employing sequences, rotations or alternations of MoA groups, IRAC is encouraging producers to clearly indicate the IRAC MoA group number and description on the product label, and to accompany this with appropriate advice of the type indicated below. Thus, in addition to the detailed product information, handling, and safety information required by local regulations, a typical label should clearly indicate the IRAC MoA Group number & description, and minimal, brief advice on IRM as indicated in the example below.

Inclusion of the IRAC group on the label is a warrant from the manufacturer that the insecticide has been classified by IRAC and is listed in Appendix 5 of this document, the only authoritative and comprehensive list of IRAC-classified insecticides. If an insecticide is not listed in Appendix 5 and falls within the scope of the IRAC classification as stated at the beginning of this document, please petition IRAC for classification of the product, as directed in Appendix 4, before drafting a label. Insecticidal materials falling outside the scope of the classification may be labeled as “Exempt from IRAC Classification”.



For resistance management purposes, Product XXX insecticide is an IRAC MoA Group 15 insecticide. Any insect population may contain individuals naturally resistant to Product XXX and other Group 15 insecticides. If these insecticides are used repeatedly, the resistant individuals may eventually dominate the pest insect population. These resistant insects may not be controlled by Product XXX insecticide or by other Group 15 insecticides. To delay the development of resistance:

- Avoid exclusive repeated use of insecticides from the same chemical sub-group, (indicated by the IRAC MoA Group number).
- Alternate with products from other IRAC MoA Groups
- Integrate other control methods (chemical, cultural, biological) into insect control programs.

For further information on resistance management and advice on IRM programmes contact your local distributor.

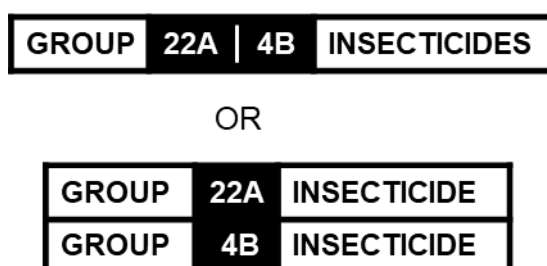
## LABELLING SPECIFICS

It is recommended that the MoA icon is displayed in a prominent position on the label. A position at the top right of the front panel of the label is strongly recommended as shown in the example above. A clearly defined font should be used, e.g., Arial or Calibri for users of Latin script. A black and white colour scheme is recommended. The icon uses the word GROUP in capital letters in black font on a white background; the mode of action letter or numeral should be in white font on a black background; the word INSECTICIDE in capital letters in black font on a white background. Both lines, and the whole indicator, are contained within black rectangles. See example below.



The words GROUP and INSECTICIDE in capital letters which should not be less than one-quarter of the height of the largest letter or numeral on the label and be between 2 mm and 12.5 mm high. If more than one insecticide is included in a product then the icon should be written in plural e.g. INSECTICIDES not INSECTICIDE. The appropriate letter(s) or number(s) representing the Mode of Action (MoA) group(s) of each active constituent(s) are to be inserted between the words GROUP and INSECTICIDE. The width of the white line that separates the groups for the pesticides in a product with more than one active ingredient should be defined. It should be wide enough so that when the icon is printed on small packets the line is clear. The letter(s) representing the mode of action should be written in capital letters which should not be less than one-half the height of the largest letter or numeral on the label and between 4 mm and 25 mm high. The words GROUP and INSECTICIDE must be no less than half, and no more than the actual size of the group number or letter.

Note that where a product has two or more active constituents, and these are represented by two or more modes of action, you must use two or more appropriate MoA identifier letters or numbers in a single statement. Alternatively, each individual active ingredient can be placed in a stacked format (see examples below).



If the product contains two or more active constituents which perform different functions, for example, an insecticide and a fungicide, you must show each function separately (that is, one indicator panel for the insecticide and another for the fungicide component). See examples below.



Where required, appropriate translation should be used to ensure MoA labels are clear to product users. Labelling should also consider the [FAO/WHO Guidelines on Good Labelling Practice for Pesticides](#). MoA labelling must follow all country regulations and may vary.

## RESISTANCE MANAGEMENT LANGUAGE FOR PRODUCT LABELS

In addition to mode of action number labelling, it is strongly recommended by CLI and the Resistance Action Committees (RACs) to include guidance on the management of resistance on the product label. Where possible companies will voluntarily add resistance management language to their product labels that explains how to use MoA information in resistance management recommendations.

IRAC recommends that resistance management guidelines be presented under a headed section titled: “**RESISTANCE MANAGEMENT**” on all insecticide labels and the following three IRM elements be incorporated in the text.

- The name of the active ingredient(s) and mode of action identifier (IRAC Mode of Action groups).
- A statement that the product should be rotated with different modes of action using mode of action treatment windows.
- Guidance to avoid treating consecutive generations with the same mode of action

### EXAMPLE OF AN IRM RECOMMENDATION ON AN INSECTICIDE PRODUCT LABEL:

*PRODUCT NAME* contains the *ACTIVE INGREDIENT NAME* and is an *IRAC GROUP X* insecticide. Do not exclusively use *PRODUCT NAME* or other *GROUP X* insecticides to control the same pest throughout the season. Avoid exposing consecutive generations of a pest to the same mode of action by using the “application window” approach which rotates products from different mode of action groups.

An “application window” is the period of residual activity that a single application or sequential applications of products from the same mode of action provide. It can also be defined as the duration of an insect generation or if unknown, then use an approximate 30 day period. Rotate windows with treatments of *PRODUCT NAME* and other *Group X* products followed by windows of treatments with other effective products with different modes of action. Multiple applications (recommend no more than two) of the same MoA insecticide are acceptable if they are used within the same application window.

Reference: [CroLife International Mode of Action Labelling Guidance](#)

## Appendix 2

### IRM principles recommended and endorsed by IRAC

- Consult a local agricultural advisor or extension services in the area for up-to-date recommendations and advice on IPM and IRM programmes.
- Consider options for minimizing insecticide use by selecting early maturing or pest-tolerant varieties of crop plants.
- Include effective cultural and biological control practices that work in harmony with effective IRM programmes. Adopt all non-chemical techniques known to control or suppress pest populations, including biological sprays such as Bt's, resistant varieties, within-field refugia (untreated areas) and crop rotation.
- Where possible select insecticides and other pest management tools that preserve beneficial insects.
- Use products at their full, recommended doses. Reduced (sub-lethal) doses quickly select populations with average levels of tolerance, whilst doses that are too high may impose excessive selection pressures.
- Appropriate, well-maintained equipment should be used to apply insecticides. Recommended water volumes, spray pressures and optimal temperatures should be used to obtain optimal coverage.
- Where larval stages are being controlled, target younger larval instars where possible because these are usually much more susceptible and therefore much more effectively controlled by insecticides than older stages.
- Use appropriate local economic thresholds and spray intervals.
- Follow label recommendations or local expert advice for use of alternations or sequences of different classes of insecticide with differing modes of action as part of an IRM strategy.
- Where there are multiple applications per year or growing season, alternate products of different MoA classes.
- In the event of a control failure, do not reapply the same insecticide but change the class of insecticides to one having a different MoA and to which there is no [locally] known cross-resistance.
- Mixtures may offer a short-term solution to resistance problems, but it is essential to ensure that each component of a mixture belongs to a different insecticide MoA class, and that each component is used at its full rate.
- Consideration should be given to monitoring for the incidence of resistance in the most commercially important situations and gauge levels of control obtained.
- Withholding use of a product to which resistance has developed until susceptibility returns may be a valid tactic if sufficient alternative chemical classes remain to provide effective control.

# Appendix 3

## MoA Group Descriptors

### NERVE AND MUSCLE TARGETS

Most current insecticides act on nerve and muscle targets. Insecticides that act on these targets are generally fast acting.

#### *Group 1: Acetylcholinesterase (AChE) inhibitors*

Inhibit AChE, causing hyperexcitation. AChE is the enzyme that terminates the action of the excitatory neurotransmitter acetylcholine at nerve synapses.

#### *Group 2: GABA-gated chloride channel blockers*

Block the GABA-activated chloride channel, causing hyperexcitation and convulsions. GABA is the major inhibitory neurotransmitter in insects.

#### *Group 3: Sodium channel modulators*

Keep sodium channels open, causing hyperexcitation and, in some cases, nerve block. Sodium channels are involved in the propagation of action potentials along nerve axons.

#### *Group 4: Nicotinic acetylcholine receptor (nAChR) competitive modulators*

Bind to the acetylcholine site on nAChRs, causing a range of symptoms from hyper-excitation to lethargy and paralysis. Acetylcholine is the major excitatory neurotransmitter in the insect central nervous system.

#### *Group 5: Nicotinic acetylcholine receptor (nAChR) allosteric modulators – Site I*

Allosterically activate nAChRs (at a site distinct from Group 32 - Site II), causing hyperexcitation of the nervous system. Acetylcholine is the major excitatory neurotransmitter in the insect central nervous system.

#### *Group 6: Glutamate-gated chloride channel (GluCl) allosteric modulators*

Allosterically activate glutamate-gated chloride channels (GluCl), causing paralysis. Glutamate is an important inhibitory neurotransmitter in insect.

#### *Group 9: Chordotonal organ TRPV channel modulators*

Bind to and disrupt the gating of Nan-Iav TRPV (Transient Receptor Potential Vanilloid) channel complexes in chordotonal stretch receptor organs, which are critical for the senses of hearing, gravity, balance, acceleration, proprioception and kinesthesia. This disrupts feeding and other behaviors in target insects.

#### *Group 14: Nicotinic acetylcholine receptor (nAChR) channel blockers*

Block the nAChR ion channel, resulting in nervous system block and paralysis. Acetylcholine is the major excitatory neurotransmitter in the insect central nervous system.

#### *Group 19: Octopamine receptor agonists*

Activate octopamine receptors, leading to hyperexcitation. Octopamine is the insect equivalent of adrenaline, the fight-or-flight neurohormone

#### *Group 22: Voltage-dependent sodium channel blockers*

Block sodium channels, causing nervous system shutdown and paralysis. Sodium channels are involved in the propagation of action potentials along nerve axons.

#### *Group 28: Ryanodine receptor modulators*

Activate muscle ryanodine receptors, leading to contraction and paralysis. Ryanodine receptors mediate calcium release into the cytoplasm from intracellular stores.

#### *Group 29: Chordotonal organ modulators – undefined target site*

Disrupt the function of chordotonal stretch receptor organs, which are critical for the senses of hearing, gravity, balance, acceleration, proprioception and kinesthesia. This disrupts feeding and other behaviors in target insects. In contrast to Group 9, Group 29 insecticides do not bind to the Nan-lav TRPV channel complex.

#### *Group 30: GABA-gated chloride channel allosteric modulators*

Allosterically inhibit the GABA-activated chloride channel, causing hyperexcitation and convulsions. GABA is the major inhibitory neurotransmitter in insects.

#### *Group 32: Nicotinic acetylcholine receptor (nAChR) allosteric modulators – Site II*

Allosterically activate nAChRs (at a site distinct from Group 5 - Site I), causing hyperexcitation of the nervous system. Acetylcholine is the major excitatory neurotransmitter in the insect central nervous system.

#### *Group 33: Calcium-activated potassium channel (KCa2) modulators*

Negative modulation of KCa2 causes hyperexcitation and convulsions. KCa2 channels are activated by increase of the intracellular calcium concentration and are involved in the regulation of action potentials.

## GROWTH AND DEVELOPMENT TARGETS

Insect development is controlled by the balance of two principal hormones: juvenile hormone and ecdysone. Insect growth regulators act by mimicking one of these hormones or directly perturbing cuticle formation/deposition or lipid biosynthesis. Insecticides that act on individual targets in this system are generally slow to moderately slow acting.

#### *Group 7: Juvenile hormone mimics*

Applied in the pre-metamorphic instar, these compounds disrupt and prevent metamorphosis.

#### *Group 10: Mite growth inhibitors affecting CHS1*

Inhibit the enzyme that catalyzes the polymerization of Chitin.

*Group 15: Inhibitors of chitin biosynthesis affecting CHS1*

Inhibit the enzyme that catalyzes the polymerization of Chitin.

*Group 16: Inhibitors of chitin biosynthesis, type 1*

Incompletely defined MoA leading to inhibition of chitin biosynthesis in a number of insects, including whiteflies.

*Group 17: Moulting disruptors, Dipteran*

Incompletely defined MoA that leads to moult disruption.

*Group 18: Ecdysone receptor agonists*

Mimic the moulting hormone, ecdysone, inducing a precocious moult.

*Group 23: Inhibitors of acetyl CoA carboxylase*

Inhibit acetyl coenzyme A carboxylase, part of the first step in lipid biosynthesis, leading to insect death.

## RESPIRATION TARGETS

Mitochondrial respiration produces ATP, the molecule that energizes all vital cellular processes. In mitochondria, an electron transport chain stores the energy released by oxidation in the form of a proton gradient, which drives ATP synthesis. Several insecticides are known to interfere with mitochondrial respiration by the inhibition of electron transport and/or oxidative phosphorylation. Insecticides that act on individual targets in this system are generally fast to moderately fast acting.

*Group 12: Inhibitors of mitochondrial ATP synthase*

Inhibit the enzyme that synthesizes ATP.

*Group 13: Uncouplers of oxidative phosphorylation via disruption of the proton gradient*

Protonophores that short-circuit the mitochondrial proton gradient so that ATP cannot be synthesized.

*Group 20; Mitochondrial complex III electron transport inhibitors – Qo site*

Inhibit electron transport complex III, preventing the utilization of energy by cells by binding to the Qo site.

*Group 21: Mitochondrial complex I electron transport inhibitors*

Inhibit electron transport complex I, preventing the utilization of energy by cells.

*Group 24: Mitochondrial complex IV electron transport inhibitors*

Inhibit electron transport complex IV, preventing the utilization of energy by cells.

*Group 25: Mitochondrial complex II electron transport inhibitors*

Inhibit electron transport complex II, preventing utilization of energy by cells.

#### *Group 34: Mitochondrial complex III electron transport inhibitors – Qi site*

Inhibit electron transport complex III, preventing the utilization of energy by cells. In contrast to Group 20, Group 34 insecticides bind to the Qi site.

## MIDGUT TARGETS

Lepidopteran-specific microbial toxins that are sprayed or expressed in transgenic crop varieties, and baculoviruses.

#### *Group 11: Microbial disruptors of insect midgut membranes*

Protein toxins that bind to receptors on the midgut membrane and induce pore formation, resulting in ionic imbalance and septicemia.

#### *Group 31: Host-specific occluded pathogenic viruses*

A baculovirus-unique Per os Infectivity Factor (PIF) protein complex on the virus promotes host-specific infection by binding to PIF targets on midgut cells that are unknown but believed to be unique for each baculovirus type. Infection is ultimately lethal.

## UNKNOWN OR NON-SPECIFIC TARGETS

Several insecticides are known to affect less well-described target-sites or functions, or to act non-specifically on multiple targets.

#### *Group 8: Miscellaneous non-specific (multi-site) inhibitors*

#### *Group UN: Compounds of unknown or uncertain MoA*

#### *Group UNB: Bacterial agents of unknown or uncertain MoA*

#### *Group UNE: Botanical essence including synthetic, extracts and unrefined oils with unknown or uncertain MoA*

#### *Group UNF: Fungal agents of unknown or uncertain MoA*

#### *Group UNM: Non-specific mechanical and physical disruptors*

#### *Group UNP: Peptides of unknown or uncertain MoA*

#### *Group UNV: Viral agents of unknown or uncertain MoA*

## Appendix 4

### Procedure for allocation of new insecticidal materials to the MoA classification

IRAC maintains the MoA Classification scheme as the definitive, globally recognised, ultimate authority on insecticide modes of action. In order to provide the best possible information for resistance management purposes, IRAC also issues regular updates of the scheme, in which newly introduced insecticides are allocated to an appropriate MoA classification group and structural sub-group, and in which re-classification or the correction of errors or anomalies for specific insecticidal agents is undertaken considering definitive new information. This document details how these processes are administered by IRAC.

### Who is responsible for the process within IRAC?

The IRAC MoA Team comprises technical representatives of the member companies with expertise in insect toxicology, pharmacology or biochemistry. All IRAC companies are eligible to contribute technical expertise to the group. The group meets regularly to consider the content and detail of the MoA scheme and makes proposals on significant additions, deletions or reallocations of insecticidal agents within the scheme for consideration by the IRAC Executive.

### Why and how often is the scheme updated?

New versions of the scheme are issued periodically as necessary, as a result of the MoA Team's consideration of new information. The introduction of major new MoA groups or the reallocation of insecticidal agents or groups would merit the issue of a new version (vN). Minor changes or corrections that do not significantly impact the scheme are undertaken automatically at intervals as necessary, and sub-versions are issued (vN.n). New sub-versions may be issued up to several times per year as required, while new full versions are not anticipated more than once per year. The potential impact of proposed significant changes on derived versions of the scheme around the world is fully appreciated, especially in countries where MoA labelling of products is used. The MoA team is cognisant of these impacts and revisions are only proposed when the evidence for change is scientifically compelling.

### What evidence is needed to support MoA classification of an insecticidal agent?

Proposals for additions to the MoA scheme or for amendments to the current scheme should be submitted to the IRAC MoA team (details below). These proposals will be considered by the Team and a decision on the outcome will be provided to the proposer in due course. Published material in high

quality, front line, peer-reviewed, scientific journals is especially useful as a source of information for consideration by the team, and those companies, bodies or individuals submitting proposals for consideration by the team are strongly encouraged to provide such information wherever possible. Corroborating information is also especially welcome. Unpublished material may be submitted in evidence, and the MoA team will interpret this appropriately.

Several types of data can be used to establish MoA (including the activation of pro-insecticides to their actives). Convincing evidence to support the MoA hypothesis is needed. This includes the demonstration of a clear target effect (activation, inhibition, or modulation) at concentrations that can reasonably be expected in the intoxicated organism. Preferably, these data may be corroborated by physiological and/or symptomology studies to link insect mortality to the effect on the target site. A positive structure-activity correlation of *in vitro* efficacy with insecticidal potency, and/or target site mutations conferring resistance are required to further substantiate the proposed MoA.

## What are the criteria for establishing MoA Sub-groups?

Sub-groups represent distinct chemical classes that are believed to have the same MoA but are different enough in chemical structure or mode of interaction with the target protein that the chance of selection for either metabolic or target-site cross-resistance is reduced compared to close analogs. Sub-groups may also distinguish insecticidal agents that are structurally similar but known to bind differently within the target or to have differential selectivity among multiple targets. Evidence supporting lack of cross-resistance between existing compounds within the Group and the new active ingredient submission must be provided to support sub-grouping. This should include bioassay based studies and provide quantifiable resistance ratios between susceptible and resistant strains.

The cross-resistance potential between sub-groups is higher than that between different groups, so rotation between sub-groups should be avoided. In exceptional circumstances (i.e., where effective registered insecticides from other mode of action groups are unavailable) rotation may be considered following consultation with local expert advice and where cross-resistance does not exist. These exceptions should not be considered sustainable resistance management strategies, and alternative options should be sought to maintain pest susceptibility.

## How are decisions made by the MoA Team?

Given the definitive nature of the IRAC MoA scheme, the MoA Team regards it as an absolute priority that the highest levels of scientific integrity are always employed in the consideration and discussion of allocation of insecticidal agents. In general, agreement on allocation of an insecticidal agent is usually arrived at through consensus within the Team, following detailed discussion. Major decisions, for example the introduction of new MoA classes or sub-classes are proposed to the IRAC Executive for ratification. If the Team cannot agree it may choose to place the case with a panel of external MoA experts to gain their written opinion before reconsidering the case. The composition of the expert panel is agreed in advance by the Team. If after reconsidering the particular case the team is still in

disagreement, the matter will be passed to the IRAC Executive for further consideration. Where individual members of the Team are subject to a conflict of interests through company affiliation or other interests, they may choose to withdraw from discussion of particular insecticidal agents as they consider appropriate.

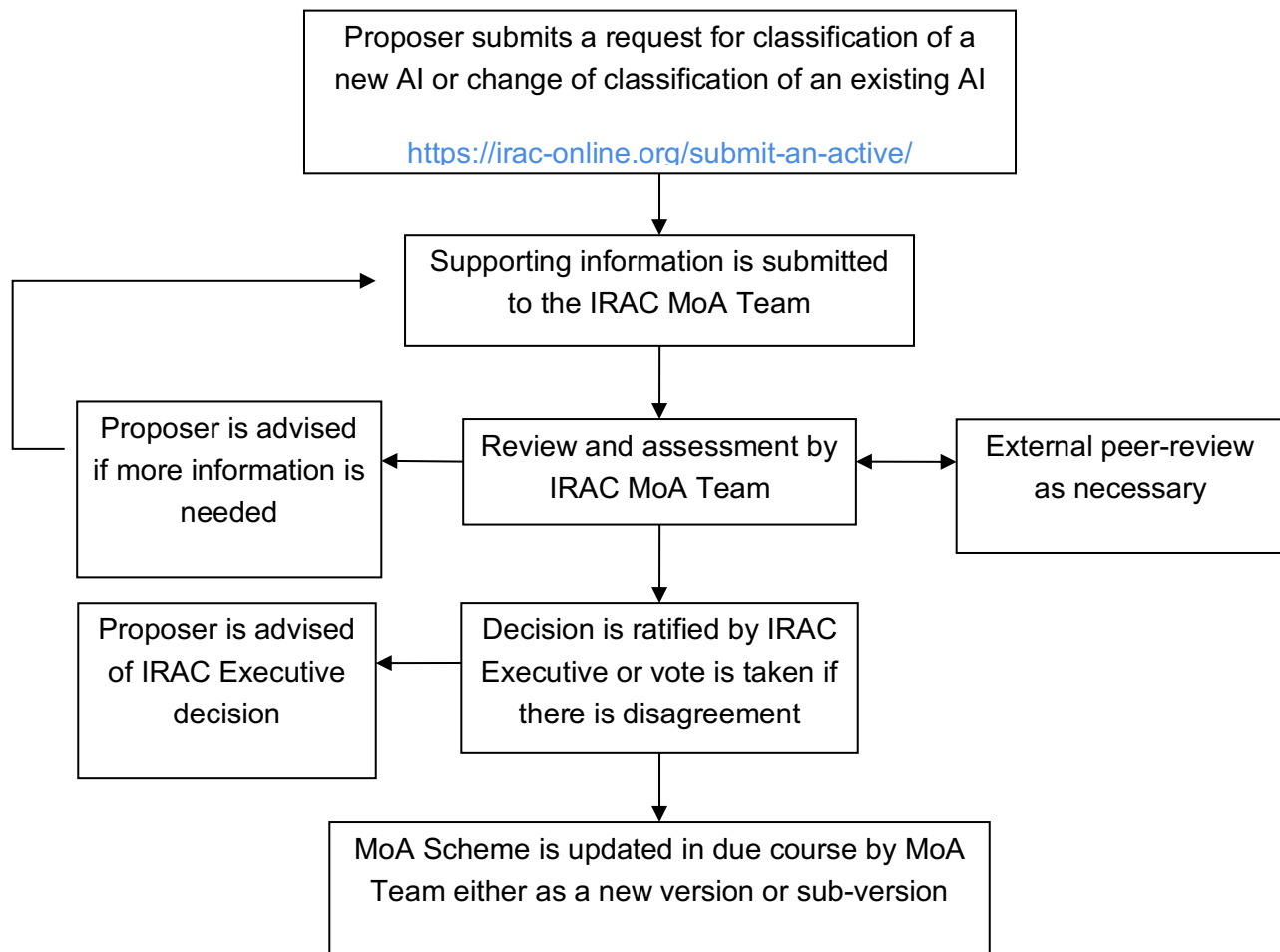
## How long does this process take?

The MoA Team has a duty to make a definitive decision on allocation of an insecticidal agent as quickly as possible following receipt of appropriate supporting evidence. For straightforward cases that do not require external consultation it should generally be expected that the Team could provide feedback to proposers within 3 months. The need for external consultants may extend the process to 6 months.

## To whom should proposals be sent?

Proposals for new insecticidal agents or for changes to the current IRAC MoA scheme should be submitted to the IRAC MoA Team via the IRAC International Coordinator. A link to the coordinator is provided on the IRAC website ([www.irac-online.org](http://www.irac-online.org)) at the bottom of each page under 'Contact'. Alternatively, the online request can be completed at <http://www.irac-online.org/submit-an-active/>

## Procedure for updates to IRAC MoA Classification Scheme



# MoA Classification Guidance Matrix

| Supporting Evidence for Classification                                                                                                                                                                                                                                                                                                                                                                                                                              | Links                                                                                                                                                                                           |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1. Existing Group</b>                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                 |
| <b>a. Existing Subgroup / no Subgroup</b>                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                 |
| <ul style="list-style-type: none"> <li>• Demonstration of a clear effect (activation, inhibition, or modulation) on the target / signal transduction pathway at concentrations that can reasonably be expected in the intoxicated organism</li> </ul>                                                                                                                                                                                                               |                                                                                                                                                                                                 |
| <ul style="list-style-type: none"> <li>• A positive structure-activity correlation of <i>in vitro</i> efficacy with insecticidal potency and/or</li> <li>• Target site mutation(s) supporting the proposed MoA</li> </ul>                                                                                                                                                                                                                                           | <a href="https://irac-online.org/documents/established-insecticide-target-site-mutations/?ext=xls">https://irac-online.org/documents/established-insecticide-target-site-mutations/?ext=xls</a> |
| <ul style="list-style-type: none"> <li>• Physiological and/or symptomology studies to link insect mortality to the effect on the target site / signal transduction pathway</li> </ul>                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                 |
| <b>b. New Subgroup (additional evidence required)</b>                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                 |
| <ul style="list-style-type: none"> <li>• Distinct chemical / biological class*</li> </ul>                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                 |
| Evidence supporting lack of cross-resistance between existing compounds within the Group and the new active ingredient: <ul style="list-style-type: none"> <li>• Quantifiable resistance ratios between field-relevant susceptible and resistant strains</li> <li>• <i>In vitro</i> studies (optional)</li> </ul>                                                                                                                                                   | resistance profiles of relevant pests incl. references<br><a href="https://irac-online.org/pests/">https://irac-online.org/pests/</a>                                                           |
| * Sub-groups may also distinguish insecticidal agents that are structurally similar but known to bind differently within the target or to have differential selectivity among multiple targets.                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                 |
| <b>2. New Group</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                 |
| <ul style="list-style-type: none"> <li>• New chemical / biological class</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                 |
| <ul style="list-style-type: none"> <li>• Demonstration of a clear effect (activation, inhibition, or modulation) on the target / signal transduction pathway at concentrations that can reasonably be expected in the intoxicated organism</li> </ul>                                                                                                                                                                                                               |                                                                                                                                                                                                 |
| <ul style="list-style-type: none"> <li>• A positive structure-activity correlation of <i>in vitro</i> efficacy with insecticidal potency and/or</li> <li>• Target site mutation(s) supporting the proposed MoA</li> </ul>                                                                                                                                                                                                                                           |                                                                                                                                                                                                 |
| <ul style="list-style-type: none"> <li>• Physiological and/or symptomology studies to link insect mortality to the effect on the target site / signal transduction pathway</li> </ul>                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                 |
| <ul style="list-style-type: none"> <li>• Clear differentiation from existing sites in a known target / signal transduction pathway is required if activity on a <u>new</u> site in an <u>existing</u> target / signal transduction pathway is claimed: this might include experimental evidence that the insecticidal agent binds to a unique site of an existing target which is not impacted by mutations conferring resistance to the existing target</li> </ul> | searchable online version of the MoA Classification<br><a href="https://www.irac-online.org/modes-of-action/">https://www.irac-online.org/modes-of-action/</a>                                  |
| <b>3. Unknown Mode of Action</b>                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                 |
| If there is insufficient evidence supporting a defined Mode of Action, insecticidal / acaricidal agents can be included in the classification scheme in the Unknown Mode of Action category they fall under: compounds, UN; bacterial agents, UNB; extracts and crude oils, UNE; fungal agents, UNF; mechanical and physical disruptors, UNM; peptides, UNP; viruses UNV                                                                                            |                                                                                                                                                                                                 |

## Appendix 5

### ACTIVE INGREDIENTS (ALPHABETICAL ORDER) WITH MOA CLASSIFICATION.

This is the comprehensive reference list of IRAC-classified insecticides. If your active ingredient is not on this list and falls within the scope of this classification as defined in section 1, please contact IRAC as directed in Appendix 4.

| Active Ingredient                 | MOA No. |
|-----------------------------------|---------|
| Abamectin                         | 6       |
| Acephate                          | 1B      |
| Acequinocyl                       | 20B     |
| Acetamiprid                       | 4A      |
| Acrinathrin                       | 3A      |
| Acynonapyr                        | 33      |
| Afidopyropen                      | 9D      |
| Alanycarb                         | 1A      |
| Aldicarb                          | 1A      |
| Allethrin                         | 3A      |
| <i>alpha</i> -Cypermethrin        | 3A      |
| Aluminium phosphide               | 24A     |
| Amitraz                           | 19      |
| <i>Anticarsia gemmatilis</i> MNPV | 31      |
| Azadirachtin                      | UN      |
| Azamethiphos                      | 1B      |
| Azinphos-ethyl                    | 1B      |

| Active Ingredient                   | MOA No. |
|-------------------------------------|---------|
| Azinphos-methyl                     | 1B      |
| Azocyclotin                         | 12B     |
| <i>Bacillus thuringiensis</i>       | 11A     |
| <i>Bacillus sphaericus</i>          | 11B     |
| <i>Beauveria bassiana</i> strains   | UNF     |
| Bendiocarb                          | 1A      |
| Benfuracarb                         | 1A      |
| Bensultap                           | 14      |
| Benzoximate                         | UN      |
| Benzpyrimoxan                       | UN      |
| <i>beta</i> -Cyfluthrin             | 3A      |
| <i>beta</i> -Cypermethrin           | 3A      |
| Bifenazate                          | 20D     |
| Bifenthrin                          | 3A      |
| Bioallethrin                        | 3A      |
| Bioallethrin S-cyclopentenyl isomer | 3A      |
| Bioresmethrin                       | 3A      |

| Active Ingredient                                                   | MOA No. |
|---------------------------------------------------------------------|---------|
| Bistrifluron                                                        | 15      |
| Borax                                                               | 8D      |
| Boric acid                                                          | 8D      |
| Broflanilide                                                        | 30      |
| Bromopropylate                                                      | UN      |
| Buprofezin                                                          | 16      |
| <i>Burkholderia spp.</i>                                            | UNB     |
| Butocarboxim                                                        | 1A      |
| Butoxycarboxim                                                      | 1A      |
| Cadusafos                                                           | 1B      |
| Calcium cyanide                                                     | 24B     |
| Calcium phosphide                                                   | 24A     |
| Carbaryl                                                            | 1A      |
| Carbofuran                                                          | 1A      |
| Carbosulfan                                                         | 1A      |
| Cartap hydrochloride                                                | 14      |
| <i>Chenopodium ambrosioides</i><br>near <i>ambrosioides</i> extract | UNE     |
| Chinomethionat                                                      | UN      |
| Chlorantraniliprole                                                 | 28      |
| Chlordane                                                           | 2A      |
| Chlorethoxyfos                                                      | 1B      |

| Active Ingredient         | MOA No. |
|---------------------------|---------|
| Chlorfenapyr              | 13      |
| Chlorfenvinphos           | 1B      |
| Chlorfluazuron            | 15      |
| Chlormephos               | 1B      |
| Chloropicrin              | 8B      |
| Chlorpyrifos              | 1B      |
| Chlorpyrifos-methyl       | 1B      |
| Chromafenozide            | 18      |
| Clofentezine              | 10A     |
| Clothianidin              | 4A      |
| Coumaphos                 | 1B      |
| Cryolite                  | 8C      |
| Cyanide                   | 24B     |
| Cyanophos                 | 1B      |
| Cyantraniliprole          | 28      |
| Cyclaniliprole            | 28      |
| Cycloprothrin             | 3A      |
| <i>Cydia pomonella</i> GV | 31      |
| Cyenopyrafen              | 25A     |
| Cyflumetofen              | 25A     |
| Cyfluthrin                | 3A      |

| Active Ingredient                                  | MOA No. |
|----------------------------------------------------|---------|
| Cyhalothrin                                        | 3A      |
| Cyhexatin                                          | 12B     |
| Cypermethrin                                       | 3A      |
| Cyphenothrin (1 <i>R</i> )- <i>trans</i> -isomers] | 3A      |
| Cyromazine                                         | 17      |
| d- <i>cis-trans</i> Allethrin                      | 3A      |
| Dazomet                                            | 8F      |
| DDT                                                | 3B      |
| Deltamethrin                                       | 3A      |
| Demeton-S-methyl                                   | 1B      |
| Diafenthiuron                                      | 12A     |
| Diatomaceous earth                                 | UNM     |
| Diazinon                                           | 1B      |
| Dichlorvos/ DDVP                                   | 1B      |
| Dicofol                                            | UN      |
| Dicrotophos                                        | 1B      |
| Diflovidazin                                       | 10A     |
| Diflubenzuron                                      | 15      |
| Dimethoate                                         | 1B      |
| Dimethylvinphos                                    | 1B      |
| Dinotefuran                                        | 4A      |

| Active Ingredient                                  | MOA No. |
|----------------------------------------------------|---------|
| Disodium octaborate                                | 8D      |
| Disulfoton                                         | 1B      |
| DNOC                                               | 13      |
| d- <i>trans</i> Allethrin                          | 3A      |
| Emamectin benzoate                                 | 6       |
| Empenthrin [(E)-1 <i>R</i> ]-isomers]              | 3A      |
| Endosulfan                                         | 2A      |
| EPN                                                | 1B      |
| Esfenvalerate                                      | 3A      |
| Ethiofencarb                                       | 1A      |
| Ethion                                             | 1B      |
| Ethiprole                                          | 2B      |
| Ethoprophos                                        | 1B      |
| Etofenprox                                         | 3A      |
| Etoxazole                                          | 10B     |
| Famphur                                            | 1B      |
| Fatty acid monoesters with glycerol or propanediol | UNE     |
| Fenamiphos                                         | 1B      |
| Fenazaquin                                         | 21A     |
| Fenbutatin oxide                                   | 12B     |
| Fenitrothion                                       | 1B      |

| Active Ingredient | MOA No. |
|-------------------|---------|
| Fenobucarb        | 1A      |
| Fenoxycarb        | 7B      |
| Fenpropathrin     | 3A      |
| Fenpyroximate     | 21A     |
| Fenthion          | 1B      |
| Fenvalerate       | 3A      |
| Fipronil          | 2B      |
| Flometoquin       | 34      |
| Flonicamid        | 29      |
| Fluacrypyrim      | 20C     |
| Flubendimide      | 28      |
| Flucycloxuron     | 15      |
| Flucythrinate     | 3A      |
| Flufenoxuron      | 15      |
| Flumethrin        | 3A      |
| Flupyradifurone   | 4D      |
| Flupyrimin        | 4F      |
| Fluxametamide     | 30      |
| Formetanate       | 1A      |
| Fosthiazate       | 1B      |
| Furathiocarb      | 1A      |

| Active Ingredient                                     | MOA No. |
|-------------------------------------------------------|---------|
| <i>gamma</i> -Cyhalothrin                             | 3A      |
| GS-omega/kappa HXTX-Hv1a                              | 32      |
| Halfenprox                                            | 3A      |
| Halofenozide                                          | 18      |
| <i>Helicoverpa armigera</i> NPV                       | 31      |
| Heptenophos                                           | 1B      |
| Hexaflumuron                                          | 15      |
| Hexythiazox                                           | 10A     |
| Hydramethylnon                                        | 20A     |
| Hydroprene                                            | 7A      |
| Imicyafos                                             | 1B      |
| Imidacloprid                                          | 4A      |
| Imiprothrin                                           | 3A      |
| Indoxacarb                                            | 22A     |
| Isocyloseram                                          | 30      |
| Isofenphos                                            | 1B      |
| Isoprocarb                                            | 1A      |
| Isopropyl O- (methoxyaminothio-phosphoryl) salicylate | 1B      |
| Isoxathion                                            | 1B      |
| Kadethrin                                             | 3A      |
| Kinoprene                                             | 7A      |

| Active Ingredient                      | MOA No. |
|----------------------------------------|---------|
| <i>lambda</i> -Cyhalothrin             | 3A      |
| Lepimectin                             | 6       |
| Lime sulfur                            | UN      |
| Lufenuron                              | 15      |
| Malathion                              | 1B      |
| Mancozeb                               | UN      |
| Mecarbam                               | 1B      |
| Metaflumizone                          | 22B     |
| Metam                                  | 8F      |
| <i>Metarhizium brunneum</i> strain F52 | UNF     |
| Methamidophos                          | 1B      |
| Methidathion                           | 1B      |
| Methiocarb                             | 1A      |
| Methomyl                               | 1A      |
| Methoprene                             | 7A      |
| Methoxychlor                           | 3B      |
| Methoxyfenozide                        | 18      |
| Methyl bromide                         | 8A      |
| Metolcarb                              | 1A      |
| Mevinphos                              | 1B      |
| Milbemectin                            | 6       |

| Active Ingredient                                 | MOA No. |
|---------------------------------------------------|---------|
| Mineral oil                                       | UNM     |
| Monocrotophos                                     | 1B      |
| Naled                                             | 1B      |
| Neem oil                                          | UNE     |
| Nicotine                                          | 4B      |
| Nitenpyram                                        | 4A      |
| Novaluron                                         | 15      |
| Noviflumuron                                      | 15      |
| Omethoate                                         | 1B      |
| Oxamyl                                            | 1A      |
| Oxazosulfyl                                       | UN      |
| Oxydemeton-methyl                                 | 1B      |
| <i>Paecilomyces fumosoroseus</i> Apopka strain 97 | UNF     |
| Parathion                                         | 1B      |
| Parathion-methyl                                  | 1B      |
| Permethrin                                        | 3A      |
| Phenothrin [(1 <i>R</i> )- <i>trans</i> - isomer] | 3A      |
| Phenthoate                                        | 1B      |
| Phorate                                           | 1B      |
| Phosalone                                         | 1B      |
| Phosmet                                           | 1B      |

| Active Ingredient      | MOA No. |
|------------------------|---------|
| Phosphamidon           | 1B      |
| Phosphine              | 24A     |
| Phoxim                 | 1B      |
| Pirimicarb             | 1A      |
| Pirimiphos- methyl     | 1B      |
| Potassium cyanide      | 24B     |
| Prallethrin            | 3A      |
| Profenofos             | 1B      |
| Propargite             | 12C     |
| Propetamphos           | 1B      |
| Propoxur               | 1A      |
| Prothiofos             | 1B      |
| Pyflubumide            | 25B     |
| Pymetrozine            | 9B      |
| Pyraclofos             | 1B      |
| Pyrethrins (pyrethrum) | 3A      |
| Pyridaben              | 21A     |
| Pyridalyl              | UN      |
| Pyridaphenthion        | 1B      |
| Pyrifluquinazon        | 9B      |
| Pyrimidifen            | 21A     |

| Active Ingredient       | MOA No. |
|-------------------------|---------|
| Pyriproxyfen            | 7C      |
| Quinalphos              | 1B      |
| Resmethrin              | 3A      |
| Rotenone (Derris)       | 21B     |
| Silafluofen             | 3A      |
| Sodium borate           | 8D      |
| Sodium cyanide          | 24B     |
| Sodium metaborate       | 8D      |
| Spinetoram              | 5       |
| Spinosad                | 5       |
| Spirodiclofen           | 23      |
| Spiromesifen            | 23      |
| Spriopidion             | 23      |
| Spirotetramat           | 23      |
| Sulfotep                | 1B      |
| Sulfoxaflor             | 4C      |
| Sulfur                  | UN      |
| Sulfuramid              | 13      |
| Sulfuryl fluoride       | 8C      |
| Tartar emetic           | 8E      |
| <i>tau</i> -Fluvalinate | 3A      |

| Active Ingredient                     | MOA No. |
|---------------------------------------|---------|
| Tebufenozide                          | 18      |
| Tebufenpyrad                          | 21A     |
| Tebupirimfos                          | 1B      |
| Teflubenzuron                         | 15      |
| Tefluthrin                            | 3A      |
| Temephos                              | 1B      |
| Terbufos                              | 1B      |
| Tetrachlorvinphos                     | 1B      |
| Tetradifon                            | 12D     |
| Tetramethrin                          | 3A      |
| Tetramethrin [(1 <i>R</i> )- isomers] | 3A      |
| Tetraniliprole                        | 28      |
| <i>Thaumatotibia leucotreta</i> GV    | 31      |
| <i>theta</i> -cypermethrin            | 3A      |
| Thiacloprid                           | 4A      |
| Thiamethoxam                          | 4A      |
| Thiocyclam                            | 14      |
| Thiodicarb                            | 1A      |
| Thiofanox                             | 1A      |
| Thiometon                             | 1B      |
| Thiosultap-sodium                     | 14      |

| Active Ingredient                | MOA No. |
|----------------------------------|---------|
| Tolfenpyrad                      | 21A     |
| Tralomethrin                     | 3A      |
| Transfluthrin                    | 3A      |
| Triazamate                       | 1A      |
| Triazophos                       | 1B      |
| Trichlorfon                      | 1B      |
| Triflumezopyrim                  | 4E      |
| Triflumuron                      | 15      |
| Trimethacarb                     | 1A      |
| Vamidothion                      | 1B      |
| <i>Wolbachia pipientis</i> (Zap) | UNB     |
| XMC                              | 1A      |
| Xylylcarb                        | 1A      |
| <i>zeta</i> -Cypermethrin        | 3A      |
| Zinc phosphide                   | 24A     |

## Appendix 6

### Active Ingredients Pending Registration

*Group numbers are proposed at this stage - the final number will be confirmed following the first registration.*

| Main Group and Primary Site of Action                                                                                                                                                                 | Sub-group, class or exemplifying Active Ingredient | Active Ingredient |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|-------------------|
| 4<br>Nicotinic acetylcholine receptor (nAChR) competitive modulators<br>Nerve action<br>{Strong evidence that action at one or more of this class of protein is responsible for insecticidal effects} | 4E<br>Mesoionics                                   | Dicloromezotiaz   |
| 35<br>RNA Interference mediated target suppressors                                                                                                                                                    | Ledprona                                           | Ledprona          |