ดร. จารุวัฒน์ นภีตะภัฏ
สถานวิจัยความเป็นที่ยศความหลากหลายทางชีวภาพแห่งคบสมุทรไทย / ภาควิชาชีววิทยา
คณะวิทยาศาสตร์
มหาวิทยาลัยสงขลานครินทร์
**Taxonomy** อนุกรมวิธาน

The theory and practice of describing, naming and classifying organisms  
Lincoln et al. (2001)

The science of classification of living organisms, 
which arranges organisms into hierarchical groupings  
Lawrence (1997)

The scientific classification of organisms  
Allaby (1999)

*taxon*, n. (taxonomic, a.) The theory and practice of classifying organisms. See taxonomic information, taxonomic taxon.  
ICZN (1999)

**Systematics** (ระบบวิทยา??)

The classification of living organisms into hierarchical series of groups 
emphasizing their phylogenetic interrelationships 
often used as equivalent to taxonomy  
Lincoln et al. (2001)

The study of the identification, taxonomy and nomenclature of organisms 
including the classification of living things 
with regard to their natural relationship, 
and the study of variation and the evolution of taxa  
Lawrence (1997)

*Systematics –* The classification of organisms into hierarchical groups based on phylogenetic relationships.  
Taxonomic Studies การศึกษาทางอนุกรมวิธาน

theory, practice of classification

theory

describing, naming, classify (review, revision)

practice

application

Identification (diversity, fauna)

Curating (collecting, transport, storage)

Publications

International Commission on Zoological Nomenclature

INTERNATIONAL CODE OF ZOOLOGICAL NOMENCLATURE

Fourth Edition
taxonomic taxon. A taxon (e.g. family, genus, species) including whatever nominal taxa and individuals a zoologist at any time considers it to contain in his or her endeavour to define the boundaries of a zoological taxon (q.v.). A taxonomic taxon is denoted by the valid name determined from the available names of its included nominal taxa.

Principle of Typification n. The principle that each nominal taxon in the family group, genus group or species group has, actually or potentially, a name-bearing type fixed to provide the objective standard of reference by which the application of the name is determined [Art. 61] (see typification).

nomenclature, n. A system of names, and provisions for their formation and use.

binominal nomenclature. The system of nomenclature in which a species, but no taxon of any other rank, is denoted by a combination of two names (a binomen, q.v.).

zoological nomenclature. The system of scientific names for animal taxa and the provisions for the formation, treatment, and use of those names.

Principle of Binominal Nomenclature n. The principle that the scientific name of a species, and not of a taxon at any other rank, is a combination of two names (a binomen, q.v.); the use of a trinomen (q.v.) for the name of a subspecies and of unnomininal names for taxa above the species group is in accord with the Principle. See Articles 5, 11.4.

Principle of Priority n. The principle that the valid name of a taxon is the oldest available name applied to it (taking into consideration the other
<table>
<thead>
<tr>
<th>Basis of concept</th>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Interbreeding</td>
<td><strong>Biological Species Concept (BSC)</strong></td>
<td>Species are groups of interbreeding natural populations that are reproductively isolated from other such groups (Mayr 1995).</td>
</tr>
<tr>
<td>2. Genetic or phenotypic cohesion</td>
<td>Genotypic Cluster Species Concept (GCS)</td>
<td>A species is a morphologically or genetically distinguishable group of individuals that has few or no intermediates when in contact with other such clusters (Mallet 1995).</td>
</tr>
<tr>
<td></td>
<td>Recognition Species Concept (RSC)</td>
<td>A species is that most inclusive population of individual biparental organisms which shares a common fertilization system (Paterson 1985).</td>
</tr>
<tr>
<td></td>
<td>Cohesion Species Concept (CSC)</td>
<td>A species is the most inclusive population of individuals having the potential for phenotypic cohesion through intrinsic cohesion mechanisms (Templeton 1989).</td>
</tr>
<tr>
<td>3. Evolutionary cohesion</td>
<td>Ecological Species Concept (EcSC)</td>
<td>A species is a lineage (or a closely related set of lineages) which occupies an adaptive zone minimally different from that of any other lineage in its range and which evolves separately from all lineages outside its range (Van Valen 1976).</td>
</tr>
<tr>
<td></td>
<td>Evolutionary Species Concept (EvSC)</td>
<td>A species is a single lineage of ancestral descendant populations or organisms which maintains its identity from other such lineages and which has its own evolutionary tendencies and historical fate (Wiley 1978, modified from Simpson, 1961).</td>
</tr>
<tr>
<td>4. Evolutionary history</td>
<td>Phylogenetic Species Concept 1 (PSC1)</td>
<td>A phylogenetic species is an irreducible (basal) cluster of organisms that is diagnosably distinct from other such clusters, and within which there is a paternal pattern of ancestry and descent (Cracraft 1989).</td>
</tr>
<tr>
<td></td>
<td>Phylogenetic Species Concept 2 (PSC2)</td>
<td>A species is the smallest [exclusive] monophyletic group of common ancestry (de Queiroz and Donoghue 1988).</td>
</tr>
<tr>
<td></td>
<td>Phylogenetic Species Concept 3 (PSC3) or Genealogical Species Concept (GSC)</td>
<td>A species is a basal, exclusive group of organisms all of whose genes coalesce more recently with each other than with those of any organisms outside the group, and that contains no exclusive group within it (Baum and Donoghue 1995; Shaw 1998).</td>
</tr>
</tbody>
</table>

*The Appendix discusses and evaluates all of these concepts except the BSC.*
**Taxonomic species = Linnaean species**

A broad concept of a species often comprising many varieties

*Lincoln et al. (2001)*

Species defined by similarities in morphological characters only, and which do not necessarily correspond to biological species

*Lawrence (1997)*

**Morphospecies**

A species established solely on morphological characters

*Lincoln et al. (2001)*

A group of biological organisms that differs in some morphological respect from all other groups

*Allaby (1999)*

A group of individuals which are considered to belong to the same species on grounds of morphology alone

*Lawrence (1997)*

<table>
<thead>
<tr>
<th>Basis of concept</th>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Interbreeding</strong></td>
<td><strong>Biological Species Concept (BSC)</strong></td>
<td>Species are groups of interbreeding natural populations that are reproductively isolated from other such groups <em>(Mayr 1995)</em>.</td>
</tr>
</tbody>
</table>
What’s the problem??

Complex กลุ่มทับซ้อน
a term for any group or assemblage of related taxa, often used when the true separation or status of the individual units is uncertain, as in species-complex

Cryptic or Sibling species ชนิดแอบแฝง
pairs or groups of closely related and frequently sympatric species which are morphologically indistinguishable but which are reproductively isolated aphanic species, twin species

past tense !! Lincoln et al. (2001)
Identification-Classification

Problems $>_<$

Species complex $>>$ cryptic species??

Variation levels??

Species variations? Population variations?

Go CSI
FIND EVIDENCES
**Taxonomic Character** ลักษณะทางอนุกรมวิธาน

is any attribute by which a member of a taxon differs or may differ from a member of another taxon

Mayr & Ashlock (1991)

a feature of organism that can be evaluated as a variable with two or more mutually exclusive and ordered states

Pimemtel & Riggins (1987) on cladistic data

**Character State** ลักษณะย่อย

one of at least two specific variations or characters that constitute a signifier, such as blue or brown in eyes

Mayr & Ashlock (1991)

Any of the range of values, conditions or expressions of a particular taxonomic character

Lincoln et al. (2001)
Taxonomic Characters

1. Morphological characters
   general external morphology
   special structure (e.g. genitalia)
   internal morphology (anatomy)
   embryology
   karyology and other cytological differences
   morphometry

2. Physiological characters
   metabolic factors
   body secretions
   genic sterility factors

3. Molecular & Biochemistry characters
   immunological distance
   electrophoretic differences
   amino acid sequences of proteins
   DNA hybridization
   DNA and RNA sequences
   allozyme and isozyme sequences
   restriction endonuclease analysis
   other molecular differences

4. Behavioural characters
   reproductive (courtship, agonistic, mating, egg laying)
   other ethological isolating mechanisms
   other behaviour patterns

5. Ecological characters
   habitats and hosts
   food
   seasonal variation
   parasites
   host reactions

6. Geographic characters
   general biogeographic distribution patterns
   sympatric-allopatric relationship of populations

7. Ontogenetic characters
   embryonic stages
   metamorphosis sequence
   stages in life history (form, duration)

Mayr & Ashlock (1991)
**Weighting of Characters**

The process by which of two conflicting characters gives the more reliable information on relationship is determined.

Can be defined as a method for inferring the phyletic information content of a character.

**Characters with High Weight**
- Complexity
- Joint possession of derived characters (apomorphy)
- Constancy
- Consistency
- Not a specific ad hoc adaptation
- Not affected by ecological shifts

**Characters with Low Weight**
- High variability
- Monogenic or oligogenic characters
- Regressive (lost) characters
- Narrow specializations

Mayr & Ashlock (1991)
Good Taxonomic Characters

readily observable characters that are believed to be fairly constant within taxa but different between taxa at any pertinent level

Simpson (1962)

The Best Key Characters

- apply to all members of the taxon
- qualitative and absolute
- observable without special equipment, dissection, or histological preparation
- fairly constant
- fairly indestructible

Winston (1999)
### Status of being “best characters for dichotomous key”

<table>
<thead>
<tr>
<th>Character</th>
<th>apply to all members of the taxon</th>
<th>qualitative and absolute</th>
<th>Observable without special equipment or preparation</th>
<th>fairly constant</th>
<th>fairly indestructible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Morphological characters</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>2. Physiological characters</td>
<td>++</td>
<td>--</td>
<td>--</td>
<td>++</td>
<td>--</td>
</tr>
<tr>
<td>3. Molecular characters</td>
<td>++</td>
<td>+-</td>
<td>--</td>
<td>++</td>
<td>--</td>
</tr>
<tr>
<td>4. Behavioural characters</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>--</td>
</tr>
<tr>
<td>5. Ecological characters</td>
<td>++</td>
<td>+-</td>
<td>+-</td>
<td>++</td>
<td>--</td>
</tr>
<tr>
<td>6. Geographic characters</td>
<td>++</td>
<td>+-</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>7. Ontogenetic characters</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>
ข้อพิจารณา

หลักฐานพอหรือไม่ ตอบคำถามได้หรือไม่
ต้องหาหลักฐานเพิ่มหรือไม่
ลักษณะและวิธีการใดที่นำมาให้คำตอบได้
จำเป็นไหม มีทางเลือกหรือไม่
เหมาะสมกับสิ่งที่เราศึกษาหรือไม่

ลักษณะแต่ละกลุ่ม แต่ละลักษณะก็เป็นอีก 1 หลักฐานที่เพิ่มขึ้นเช่นกัน
<table>
<thead>
<tr>
<th>Marker</th>
<th>Genome</th>
<th>Develop time</th>
<th>Cost</th>
<th>Btw study comparison</th>
<th>Suitability for evolutionary studies</th>
<th>Cover</th>
<th>Genotyping</th>
<th>DNA quality</th>
<th>Overall variability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allozymes</td>
<td>Nuclear</td>
<td>Low</td>
<td>Low</td>
<td>Limited</td>
<td>Limited</td>
<td>Med</td>
<td>Easy</td>
<td>Med</td>
<td>Low-Med</td>
</tr>
<tr>
<td>RFLP</td>
<td>Nuclear, Organelle</td>
<td>Med</td>
<td>Low</td>
<td>Limited</td>
<td>Limited</td>
<td>Med</td>
<td>Easy</td>
<td>Med</td>
<td>Low-Med</td>
</tr>
<tr>
<td>DNA sequencing</td>
<td>Nuclear, Organelle</td>
<td>Low – Med</td>
<td>Med</td>
<td>Yes</td>
<td>High</td>
<td>Low</td>
<td>Med</td>
<td>Med</td>
<td>Low-Med</td>
</tr>
<tr>
<td>SNPs</td>
<td>Nuclear, Organelle</td>
<td>Med – High</td>
<td>Med-High</td>
<td>Yes</td>
<td>High</td>
<td>High</td>
<td>Easy</td>
<td>High</td>
<td>Med</td>
</tr>
<tr>
<td>Microsats</td>
<td>Nuclear, Organelle</td>
<td>High</td>
<td>Med-High</td>
<td>Limited (depends on called peaks)</td>
<td>Limited</td>
<td>Med</td>
<td>Difficult</td>
<td>Med</td>
<td>High</td>
</tr>
</tbody>
</table>

Development time – assumes markers not yet developed
Cost is quickly changing for some markers with advances in NGS
Cover – Amount of the genome screened
Genotyping – Difficulty in consistently and accurately identifying genotype
New Techniques

Molecular
New Generation Sequencing (NGS) and Genomics:

whole genome sequencing (WGS),
genotype-by-sequencing (GBS),
Restriction Endonuclease (RE) methods,
Restriction-site Associated DNA sequencing (RAD-seq),
Amplicon sequencing,
Metagenomics,
Gene Expression
New Techniques > Non-Destructive Method

Morphology
quantitative-morphometry: multivariate statistics, PCA, DA, Cluster, geometric

qualitative: SPM (scanning probe micrography),
Tomography is the technique of
1. using ultrasound, gamma rays, or X-rays to obtaining a series of detailed pictures of areas inside the object (imaging);
2. the pictures are created by a computer linked to the imaging machine
   CT scan, PET scan, MRI scan, X-ray synchrotron beam

CT (Computed Tomography) Scan / CAT (Computed Axial Tomography) scan
X rays at different angles > cross-sectional images (slices) of the tissue

PET (Positron Emission Tomography)
detection of electron-positron annihilation, converts to X-rays in opposite directions

MRI (Magnetic Resonance Imaging) / NMR (Nuclear Magnetic Imaging)
detection radio wave energy of protons in a strong magnetic field

3D Imaging and Reconstruction
Geometric Morphometry & 3D Reconstruction
Tomography