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REQUIREMENTS FOR PHARMACEUTICALS FOR HUMAN USE

ICH HARMONISED GUIDELINE

**NONCLINICAL SAFETY TESTING IN SUPPORT OF
DEVELOPMENT OF PAEDIATRIC MEDICINES
S11**

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ICH Consensus Guideline

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1 **LIST OF ABBREVIATIONS**

2

3	ADME	Absorption, Distribution, Metabolism, and Excretion
4	CNS	Central Nervous System
5	CT	Computed tomography
6	DRF	Dose Range-Finding
7	ePPND	Enhanced Pre- and Postnatal Development
8	FIH	First in Human
9	FOB	Functional Observational Battery
10	GI	Gastrointestinal
11	ICH	International Council on Harmonisation
12	JAS	Juvenile Animal Study
13	NHP	Non-Human Primate
14	NOAEL	No-Observed Adverse Effect Level
15	PND	Postnatal Day
16	PPND	Pre- and Postnatal Development
17	PK	Pharmacokinetics
18	PD	Pharmacodynamics
19	TDAR	T-Cell-Dependent Antibody Response
20	TK	Toxicokinetic
21	WoE	Weight of Evidence

22 1. INTRODUCTION

23 1.1 Objectives of the Guideline

24 The purpose of this document is to recommend international standards for, and promote
25 harmonisation of, the nonclinical safety studies recommended to support the development of
26 paediatric medicines. Harmonisation of the guidance for nonclinical safety studies will define
27 the current recommendations and reduce the likelihood that substantial differences will exist
28 among regions. It should facilitate the timely conduct of paediatric clinical trials and reduce the
29 use of animals in accordance with the 3Rs (replace/reduce/refine) principles.

30 1.2 Background

31 Several regional guidelines have previously been issued by various regulatory agencies and
32 were not in complete agreement on the need for, timing of, and design of juvenile animal
33 studies (JAS).

34
35 There are ICH guidelines that refer to the need for and/or timing or study design of JAS (e.g.,
36 ICH E11, M3, S5, S6, and S9); the current guideline is intended to complement the existing
37 ICH guidelines. This guideline reflects current thinking based on collations of examples by
38 regulatory agencies, by industry surveys, and literature.

39 1.3 Scope

40 This guideline recommends an approach for the nonclinical safety evaluation of medicines
41 intended for development in paediatric populations. This can include products with prior adult
42 use, as well as products being considered for initial human use in paediatrics (see Section 4).

43 The ICH S9 guideline should be consulted for recommendations on whether to conduct JAS for
44 those pharmaceuticals included in the scope of the ICH S9 guideline, i.e., anticancer
45 pharmaceuticals. The ICH S11 guideline should be consulted for study design in all cases
46 where a study is considered to be warranted.

47 Tissue engineered products, gene and cellular therapies, and vaccines are excluded from the
48 scope of this guideline.

49 1.4 General Principles

50 Paediatric patients represent a population different from adults when considering the rapid
51 growth and postnatal development of several organ systems. The continued development of
52 these systems can affect drug pharmacokinetics (PK), pharmacodynamics (PD), and/or off-target
53 effects of medicines, potentially leading to differences in toxicity and/or efficacy profiles both
54 between paediatric age groups and when compared to adults.

55 An early consideration of nonclinical support for paediatric medicine development is
56 recommended. In this respect, changing the design and/or timing of the traditional nonclinical
57 program is one way to address potential safety concerns for the paediatric patient. For example,
58 dosing can be initiated at a younger age in a repeat-dose toxicity study to support the
59 corresponding developmental stages in paediatric patients. Another approach could be to conduct
60 the Pre- and Postnatal Development (PPND) study earlier than usual, with modifications that
61 demonstrate adequate offspring exposure and incorporate additional endpoints (see ICH S5).
62 These changes can obviate the need for, or limit the design of, a dedicated JAS.

63 An understanding of the overall clinical development plan is needed to design an appropriate,
 64 efficient nonclinical plan. Prior to each paediatric trial, a weight of evidence (WoE; see Section
 65 2) based decision should be made to determine whether additional nonclinical investigations are
 66 warranted. The outcome of such a WoE assessment can be different for each trial for the same
 67 pharmaceutical depending on paediatric age and indication.

68 The conduct of additional nonclinical investigations should be undertaken only when previous
 69 animal and human data are judged to be insufficient to support paediatric studies. JAS are
 70 designed to address identified safety concerns that cannot be adequately addressed in other
 71 nonclinical studies or paediatric clinical trials, including potential long-term safety effects. This
 72 guideline recommends a customized JAS that comprises core design elements and potential
 73 additional elements driven by specific concerns.

74 **2. DETERMINING THE NEED FOR ADDITIONAL NONCLINICAL SAFETY**
 75 **INVESTIGATIONS**

76 **2.1 Clinical Context**

77 The paediatric clinical development plan for a pharmaceutical is discussed in the ICH E11
 78 guideline, and needs to be understood before an appropriate nonclinical plan can be designed.
 79 The paediatric clinical plan includes the indication/condition, the intended paediatric age
 80 group(s), and the treatment regimen (particularly, the duration of dosing during the stages of
 81 development). The clinical development of a medicine for paediatric patients usually follows
 82 initial adult clinical studies. If needed, the design and timing of additional nonclinical
 83 investigations are dependent on the identified safety concerns and the intended clinical use.

84 In case of a severely debilitating or life-threatening disease, or one in which there is serious unmet
 85 medical need in a paediatric population, the sponsor and regulatory agencies should consider the
 86 timing impact of producing additional data to support patient access to a pharmaceutical. This
 87 decision should be based upon a careful and cautious risk-benefit evaluation. If a safety concern
 88 is identified for further clinical development, appropriate nonclinical studies (e.g., JAS) should
 89 be considered, and could be conducted in parallel with clinical investigation.

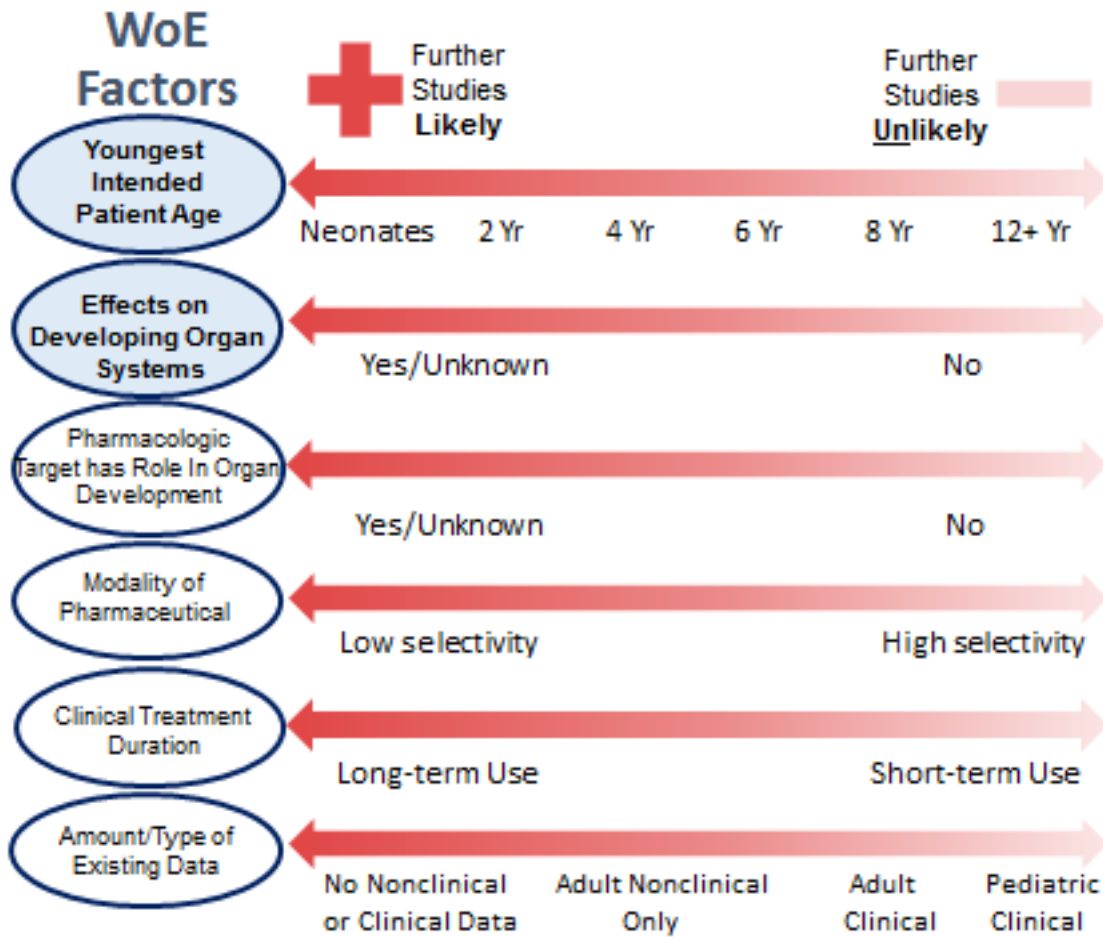
90 **2.2 Weight of Evidence Approach**

91 The nonclinical development plan for a paediatric pharmaceutical depends on an integrated
 92 assessment based on the totality of the clinical context together with the pharmacology,
 93 pharmacokinetic (ADME), and nonclinical *in vitro* and *in vivo* animal and clinical safety data,
 94 i.e., a WoE approach. A WoE approach considers multiple factors evaluated together and,
 95 therefore, a single factor should not be considered in isolation. The importance of each factor
 96 should be weighted such that the final decision concludes whether available data adequately
 97 address safety concerns in the proposed paediatric population or whether additional nonclinical
 98 studies are warranted.

99 The WoE evaluation should be conducted when designing the initial paediatric development plan,
 100 but revisited if there are changes in age ranges and/or indications. The WoE outcome can be
 101 different for each trial depending on the paediatric population and the disease to be treated.

102 Figure 1 below shows some key factors that should be considered as part of the WoE evaluation
 103 to determine the need for further nonclinical investigations. The individual factors are

104 presented below on the left of the figure. The most important factors are the youngest intended
 105 patient age and whether there are known (or suspected) adverse effects on developing organ
 106 systems of the patients during the conduct of the paediatric trial. The other important factors
 107 are not listed in order of weight in the figure. The list is not all inclusive for every situation, as
 108 there may be additional specific factors to consider (e.g., clinical management). The WoE
 109 factors are further described in the following sections.



110
 111 Figure 1: Key Weight of Evidence factors to be considered in determining if nonclinical studies
 112 are warranted. The most important factors are the youngest intended patient age and whether
 113 there are known (or suspected) adverse effects on developing organ systems of the patients during
 114 the conduct of the paediatric trial. The other important factors are not listed in order of weight.
 115 The arrows indicate a gradient for the weight of each factor.

116 **2.3 Factors to Inform the Weight of Evidence Evaluation**

117 **2.3.1 Clinical Information**

118 The most relevant safety and efficacy data for paediatric patients come from other paediatric
 119 subpopulations and adults exposed to the pharmaceutical. This established efficacy and safety
 120 profile is usually the first point to consider when determining if additional nonclinical studies are
 121 warranted.

122 The youngest intended patient age is one of the most important factors to be considered. The
123 use of existing clinical data from older subgroups may not necessarily be sufficient (see ICH
124 E11). Further nonclinical studies are more likely to be warranted at the lower end of the age
125 range.

126 The duration of clinical treatment is another factor in determining whether additional nonclinical
127 studies are warranted. Longer durations of treatment are more likely to expose a paediatric
128 subject during a developmentally sensitive window. Whereas short-term use of a
129 pharmaceutical is less likely to affect some aspects of development such as growth, a long
130 duration of use is more likely to warrant further nonclinical studies than short-term treatments.

131 Additional nonclinical studies are not warranted when existing clinical data are considered
132 sufficient to support paediatric use and/or if identified safety concerns can be clinically managed.
133 A JAS is not warranted to confirm toxicity in target organs in which sensitivity to toxicity is not
134 expected to differ between adults and paediatric patients. Developmental differences in target
135 or off-target tissue maturity do not, in isolation, necessarily mean a JAS is required, but are a
136 concern that needs to be considered.

137 2.3.2 *Pharmacological Properties*

138 Primary or secondary pharmacological properties of a pharmaceutical can be responsible for
139 unwanted side effects. This may raise concerns for paediatric use if effects occur in
140 systems/organs in development and/or if developing organs have a different sensitivity from
141 mature organs. A review of the literature on the developmental expression and ontogeny of
142 drug target(s) (e.g., receptor, enzyme, ion channels, protein), or the known/potential role of the
143 target during development is recommended. Existing data from genetically modified animals
144 (e.g., the knock-out of a receptor) may also identify developmental effects of potential concern
145 for the paediatric population, which could be included in the WoE evaluation.

146 If the known pharmacology of a medicine has the potential to impact the development of the
147 intended paediatric population, or the role of the pharmacology on development is not understood
148 or reasonably predictable, further nonclinical investigations should be considered. Potential
149 adverse effects of pharmaceuticals with high selectivity for their target (e.g., monoclonal
150 antibodies) are more likely to be related to exaggerated pharmacology and therefore be more
151 predictable than effects of pharmaceuticals with lower selectivity for their pharmacologic target.
152 Pharmaceuticals with lower selectivity may have secondary pharmacodynamic effects and thus
153 are more likely to warrant further nonclinical investigations. Considerations should be given
154 whether conducting *in vitro* or *ex vivo* investigations using juvenile (i.e., animal) or paediatric
155 (i.e., human) tissues would be useful to determine potential age-related differences in sensitivity,
156 density, and distribution of molecular pharmacological/toxicological targets.

157 Further nonclinical studies might not add value when the underlying pharmacology has already
158 identified a particular hazard.

159 2.3.3 *Pharmacokinetic Data*

160 Important differences can exist in the ADME of pharmaceuticals depending on the age of both
161 patients and animals, leading to potential differences in efficacy and toxicity. These differences
162 are usually most prominent in neonates and infants. Similarly, maturation of the gastrointestinal

163 (GI), liver, and renal systems can result in rapidly changing systemic exposures, particularly in
164 young animals.

165 The use of clinical PK modelling and simulation systems for the purpose of predicting PK/ADME
166 characteristics in paediatric populations can be more relevant than conducting JAS. If the
167 results of the PK modelling and simulation indicate that there will be significant differences
168 between adult and paediatric patients, then nonclinical investigations (e.g., *in vitro* studies) can
169 be helpful to determine the potential impact of these differences on toxicity.

170 **2.3.4 Nonclinical Safety Data**

171 Existing nonclinical toxicity study data should be evaluated for signals that could indicate
172 potential effects in organs undergoing development in paediatric subjects. Findings occurring
173 in animals at similar exposures as those likely to be achieved in paediatric subjects are of higher
174 concern, particularly if the findings occur in organs/tissues that undergo significant postnatal
175 development at the intended paediatric age (see Appendix A). Safety signals that occur in adult
176 animals of more than one species are of increased concern. Depending on the age of the animals
177 at study start and the endpoints included, some of these concerns may have been addressed in
178 existing repeat-dose toxicity studies.

179 Genotoxicity testing and safety pharmacology investigations are normally conducted to support
180 adult clinical trials and, therefore, should be available before paediatric clinical trials commence.
181 If a safety pharmacology study shows an effect in an organ system known to be developing in
182 the intended paediatric patient population, the possible impact of the effect should be carefully
183 considered. Additional genotoxic and safety pharmacology assessments in juvenile animals are
184 generally not needed to support paediatric indications.

185 Reproductive and developmental toxicity study data may also be available. If PPND study data
186 are available and have shown clinically relevant and sustained systemic exposures in offspring
187 during the relevant postnatal period, these data can contribute to the WoE evaluation. The review
188 of such data should include the maternal tolerance of the drug during pregnancy and lactation, as
189 this could have impacted on the findings in the offspring. Observations of adverse effects in
190 offspring would not, on their own, indicate that a JAS is recommended. However, if there is an
191 identified safety concern that could lead to effects on postnatal development, it should be
192 considered in the WoE evaluation. These data in rodents are primarily relevant to preterm and
193 term neonates if exposure is demonstrated.

194 In some cases modification of a rodent PPND study can obviate the need for a JAS, provided
195 potential concerns for the paediatric population have been appropriately addressed in the study
196 design (see ICH S5). For enhanced PPNDs (ePPND) studies conducted in the non-human
197 primate (NHP), the data from the offspring can characterize toxicity during early postnatal
198 development, provided relevant exposure and/or PD effects are confirmed in the offspring.
199 When available, ePPND data should be evaluated in combination with data from the general
200 toxicity studies in assessing the value of additional nonclinical investigations.

201 **2.3.5 Feasibility**

202 The decision to conduct an additional animal study should also consider the technical and
203 practical feasibility of the study design and endpoints (see Section 3). If a study in animals
204 cannot be conducted with dose levels that provide acceptable systemic exposures in the range of

205 those expected in paediatric patients, even with an alternative route of administration or
206 frequency of dosing, the conduct of the JAS may not be informative or warranted.

207 **2.4 Application and Outcome of the Weight of Evidence Evaluation**

208 All of the WoE factors described above should be considered when determining whether
209 additional nonclinical investigations are warranted. Additional nonclinical studies are not
210 warranted if identified safety concerns can be clinically monitored and/or managed. When a
211 study is warranted, the specifics of the identified safety concerns will define the objectives of the
212 nonclinical investigation; this could be a JAS or another study (e.g., *in vitro* or *ex vivo*
213 investigations).

214 Examples of applying the WoE approach are in Appendix B.

215 **3. DESIGN OF NONCLINICAL JUVENILE ANIMAL STUDIES**

216 **3.1 General Considerations/Study Objectives**

217 Once it is decided that a JAS is warranted, Section 3 should be consulted to design the appropriate
218 study. This section contains recommendations on study design considerations, core endpoints
219 to be included in all studies, and additional endpoints that can be included to address specific
220 concerns. A JAS design including all potential additional endpoints is not recommended
221 without rationale.

222 If the reason to conduct a study is primarily driven by a specific, identified safety concern for
223 paediatric patients, the study design should be customized to address particular aspects of
224 function or development of a target organ or system of concern. If the rationale to conduct a
225 study is based on a concern for patient safety due to lack of relevant knowledge of the
226 pharmacology, the study design would generally be broader and include additional endpoints as
227 appropriate.

228 The maturation of human and animal organ systems can influence susceptibility to toxicity.
229 Understanding the relative level of maturity and function across species during development is
230 needed not only to design the appropriate JAS but also to aid the translation of nonclinical toxicity
231 findings to a specific human age range. This “age” or “stage” mapping can be challenging and
232 is not uniform across different organ systems or species, as the relative maturity at birth, rate of
233 postnatal maturation, and/or regulation of maturation can be quite different between humans and
234 animals. While not comprehensive, Appendix A, Figures A1-A6 provide an overview of age-
235 dependent development of organ systems by species.

236 **3.2 Preliminary/ Dose Range Finding Studies**

237 Preliminary studies such as dose range-finding (DRF) or PK studies with small group sizes of
238 juvenile animals of relevant age are highly recommended to perform tolerability and PK/TK
239 (toxicokinetic) assessments. This is particularly valuable when dosing starts prior to weaning
240 to avoid unexpected mortality, excessive toxicity, and/or irrelevant exposures in a definitive JAS.

241 Dosing should be initiated at the youngest planned starting age of the animals in the definitive
242 JAS to evaluate the most critical period for tolerability and exposure differences. The DRF
243 dosing period generally lasts a few weeks, e.g., typically until shortly after weaning in rodents.
244 If there are important age-related differences in tolerated dose levels between adults and juveniles,

245 a second DRF study may be needed to select adequate dose levels or a dosing regimen for the
 246 definitive JAS. See sections on route of administration (3.6) and dose selection (3.7) for more
 247 information on the use of preliminary studies to prepare for anticipated changes in dosing route
 248 and/or dose level adaptation during the course of a definitive JAS.

249 In a preliminary or DRF JAS, lack of tolerability of a pharmaceutical at clinically relevant
 250 systemic exposures can indicate a significant concern for the corresponding clinical age range.
 251 When the reason for greater sensitivity or significant differences in toxicity profiles between
 252 juvenile and adult animals at similar systemic exposure is not understood, additional
 253 investigations (e.g., assessment of protein-binding values or blood-brain barrier penetration) can
 254 be useful for the interpretation of these differences.

255 In certain circumstances, DRF studies can explore the usefulness of particular endpoints, tissues,
 256 or biomarkers and thus refine the study design of the definitive JAS.

257 **3.3 Animal Test System Selection**

258 When a JAS is warranted, in most cases a single species is considered sufficient. In principle, the
 259 rat should initially be considered as the species for a JAS. Other species have been used in JAS
 260 (e.g., mouse, rabbit, dog, minipig, NHP). In all cases, the selected species should be justified, as
 261 nonclinical studies in a non-relevant species can give rise to misinterpretation and are not
 262 recommended.

263 The following factors should be considered when selecting an appropriate species:

- 264 • An understanding of the ontogeny of the pharmacological or toxicological target (e.g., the
 265 receptor) in animals in comparison to that in the intended paediatric population
- 266 • Preference for a species and strain for which adult repeated-dose toxicity data are available
 267 to allow a comparison of the toxicity and systemic exposure profiles between juvenile and
 268 adult animals.
- 269 • Toxicological target organs
 - 270 ○ the relative stage of organ/system development in the juvenile animal as compared to the
 - 271 intended paediatric population (see also Section 3.4)
 - 272 ○ the ability of the animal model to detect toxicity endpoints of concern
- 273 • The technical/practical feasibility to conduct the study in the selected species
- 274 • Similarity of ADME characteristics

275 Advantages and disadvantages of using different rodent or non-rodent species are outlined in
 276 Appendix A, Table A1.

277 While for biopharmaceuticals NHPs are pharmacological responders in many cases, the conduct
 278 of JAS in NHPs is challenging for both scientific and practical reasons. There is limited added
 279 value of performing JAS in younger NHP as compared to the 2-4 year old NHP used in general
 280 toxicity studies and, therefore, alternative approaches to obtaining the necessary data are
 281 encouraged. Only in rare cases is the value of JAS conducted in NHP justifiable.

282 Consistent with ICH S6, a homologous protein, when available, can be considered for the
 283 purposes of hazard identification in the rodent or other non-rodent species.

284 JAS in two species would be warranted only in a paediatric-first situation (see Section 4) or where
285 there are multiple specific concerns for postnatal development and one species alone is not able
286 to address them.

287 If a paediatric PD model of disease exists (e.g., enzyme replacement therapy), appropriate safety
288 endpoints can be incorporated in these studies. This information could contribute to the WoE
289 evaluation and/or potentially obviate the need for a dedicated JAS.

290 **3.4 Age of Animals, Dosing Period, and Dosing Regimen**

291 The age of dosing initiation in animals should developmentally correspond to the youngest age
292 of the intended paediatric population, which will depend on a human-to-animal comparison of
293 developmental periods of organ system(s) of toxicological concern. As comparative organ
294 system correlations are not aligned for each organ across species, priority should be given to any
295 target organ/ system of potential concern or to particularly vulnerable developing systems in the
296 intended patient population. The animal age at dosing initiation should be justified using
297 relevant information (see Appendix A).

298 When determining the duration of administration in JAS, it is important to consider the age range
299 and the shorter developmental period of animals compared to humans, the duration of treatment
300 for the intended paediatric population, the safety concern to be assessed, and the developmental
301 stage of target organs/functions of the intended paediatric population relative to that of the
302 animals used for toxicology studies.

303 The dosing period in JAS is not only defined by the paediatric age stages (e.g., > 2 years) or the
304 clinical dosing duration but also by the specific stages of organ development for the organs of
305 concern (see Appendix A). To evaluate the impact on a paediatric developmental stage, a longer
306 dosing period in animals can be appropriate to address a concern of a certain organ system that
307 develops late (e.g., central nervous system [CNS]) compared to a system with shorter
308 developmental window (e.g., kidney). In contrast to nonclinical studies for adult populations
309 (see ICH M3), a short treatment duration in paediatric patients can require a longer dosing
310 duration in the JAS to capture the developmental age range of the intended paediatric population.
311 For example, to include the youngest intended patients of 2 years old up to patients 12 years of
312 age with a clinical dosing duration of 14 days, the JAS can have a dosing period longer than 14
313 days to incorporate exposure at all developmental stages corresponding to human patients from
314 2 to 12 years old (e.g., in the rat this would be approximately 6 weeks dosing duration, roughly
315 postnatal day (PND) 21 to 65, See Appendix A).

316 Dosing up to maturation can be feasible in non-rodent species like the dog, minipig, and rabbit,
317 as these species mature over a period of a few to several months, and with relative consistency.
318 In contrast, the interval between birth and maturity for NHPs is several years, making dosing
319 during the entire developmental period not practical. Furthermore, NHPs show considerable
320 inter-individual variation in the age of onset of puberty and maturity.

321 When a DRF study demonstrates that a dose level or duration of dosing is not expected to be
322 tolerable in a JAS, it may be possible to achieve the clinically relevant exposure at this dose by
323 separating the dosing period into different subgroups (e.g., a required 6-week JAS dosing period
324 is split into two subgroups of 3 weeks dosing, each starting at different ages). This approach
325 may only be needed at the dose that is not tolerated. This approach is especially applicable in

326 cases when the clinical dosing period is comparable to or shorter than the dosing period in the
327 JAS subgroups; it may also have value to identify critical windows of susceptibility. The benefits
328 of this approach should be considered with the drawbacks, such as substantially increasing the
329 required number of animals and difficulties interpreting data at different ages. See Section 3.7
330 Dose Selection regarding dose adjustment as an alternate strategy to be considered in this
331 situation.

332 Dosing frequency in JAS may not be exactly the same as in the clinical regimen. For example,
333 even though a clinical regimen is once a week, daily dosing in juvenile animals can be needed to
334 achieve and maintain relevant systemic exposures to evaluate the effects on developing organ
335 systems and/or to maintain systemic exposures at relevant levels during the entire developmental
336 period of concern.

337 **3.5 Off-Treatment Period Assessments**

338 Inclusion of an evaluation period after treatment has stopped in a JAS can help address two
339 issues: 1) whether any effects observed during treatment are reversible, persistent, or progressive
340 and 2) whether any effects emerge later in development as a result of early life exposure (i.e.,
341 delayed onset of changes). The need for an off-treatment period is dependent on the outcome
342 of the WoE assessment and the endpoints to be evaluated in the study.

343 In general, an off-treatment period should be included to understand persistence, progression, or
344 reversibility of a specific effect if this cannot be predicted by scientific assessment (Note 1).
345 The principles of reversibility in ICH M3 apply to JAS endpoints that are similar to those in
346 repeat-dose toxicity studies in adults (e.g., histopathology, clinical pathology). The duration of
347 such an off-treatment period should be sufficient to allow the potential recovery of the effect, and
348 should take into account the elimination of the pharmaceutical. The demonstration of full
349 reversibility is not considered essential. A trend towards reversibility (decrease in incidence
350 and/or severity) and a scientific assessment that this would eventually progress to full
351 reversibility could be sufficient. If reversibility or irreversibility of a specific effect is well
352 characterized in adult animals, it is generally not necessary to confirm this in a JAS. There are
353 endpoints in a JAS that are not amenable to the classic approach of reversibility assessment, such
354 as the timing of onset of puberty and neurobehavioral assessments (e.g., learning). Additionally,
355 the timing of the off-treatment period in relation to the life stage of the animals should be
356 considered

357 Some alterations can only be identified following an appropriate off-treatment period to allow
358 maturation of an organ system and expression of the alteration. Therefore, some assessments
359 can only be meaningfully performed after a certain level of maturity is expected to be reached
360 (e.g., behavioural assessment, immunological response in T-cell-dependent antibody response
361 [TDAR]). These assessments can be conducted in off-treatment periods after dosing duration
362 has covered all critical developmental windows related to the clinical use. This is especially
363 relevant in cases in which the clinical population is only the very young, such that the JAS dosing
364 duration would cease at an immature age and the animals will continue to mature during the off-
365 treatment period to an age that an appropriate assessment can be conducted.

366 In non-rodents, the addition of post-treatment groups for JAS can be less useful due to the more
367 protracted development period, high inter-individual variability, and fewer and less well
368 characterized assessments available to identify delayed or altered development.

369 3.6 Route of Administration

370 The intended clinical route of administration should be used when feasible, but obtaining
371 adequate systemic exposure is paramount.

372 Alternative administration routes should be considered in cases of practical difficulties; changing
373 routes during the course of the study can also be considered (e.g., subcutaneous until intravenous
374 is feasible in rodents). The validity of using an alternative dosing route should be justified (e.g.,
375 supported by TK data in representative juvenile animals).

376 If the pharmaceutical is intended for use by two or more clinical routes of administration, a JAS
377 with a single route of administration is sufficient, but should provide adequate exposure in
378 juvenile animals for all intended clinical routes of administration.

379 3.7 Dose Selection

380 It is desirable to establish a dose-response relationship for adverse effects and to determine a no-
381 observed adverse effect level (NOAEL) in juvenile animals. Dose levels should be selected to
382 achieve some overlap in the range of exposure in adult animals to enable comparison of effects
383 between adults and young animals. However, the high dose should not result in marked toxicity
384 that can confound the growth and development endpoints and complicate the assessment. Body
385 weight loss or lack of gain during rapid growth periods has the potential to confound results, and
386 is therefore not desirable in a JAS. The low dose should preferably result in exposure levels
387 similar to the anticipated exposure in the intended clinical population. For small molecules,
388 selection of the high dose in accordance with ICH M3 applies. For biotechnology-derived
389 products, the principles for dose selection described in ICH S6 apply.

390 There can be changes in systemic exposure due to maturation of the ADME systems that can
391 make it challenging to meet the dose selection aims described above. In cases in which
392 preliminary studies demonstrated that juvenile animals are markedly more sensitive than adult
393 animals, or there are substantial changes in systemic exposure as the animals mature, dose
394 adjusting should be considered. Dose adjustment (dose increase or decrease) during a JAS can
395 be appropriate to evaluate endpoints when exposure separation between dose levels can otherwise
396 not be maintained throughout the study. Adjusting doses during the study is intended to keep
397 the exposures somewhat consistent; generally, not more than one or two adjustments during a
398 JAS would be expected.

399 3.8 Endpoints

400 Each JAS should include the core endpoints defined in Section 3.8.1 below, unless justified
401 otherwise. Each additional endpoint (see Section 3.8.2) should be considered and justified to
402 address an identified safety concern (Note 2).

403 For the interpretation of study results in JAS it is important to have appropriate historical
404 control data (HCD) at relevant ages of the species/strain/sex used (Note 3).

405 **3.8.1 Core Endpoints**406 **3.8.1.1 Mortality and Clinical Observations**

407 Mortality should be evaluated throughout the experimental period. Clinical observations,
408 including physical examinations, should be conducted as they can identify overt behavioural
409 effects both on and off treatment

410 Clinical observations during the lactation period should include maternal nursing behaviour, and
411 should capture clinical observations unique to juvenile animals as much as possible. After
412 weaning, clinical observations should be recorded as for adult animals.

413 **3.8.1.2 Growth**

414 Growth should be assessed by body weights in conjunction with long bone length. As body
415 weight increases dramatically during the early postnatal period, individual weight measurements
416 should be frequently recorded to inform dose calculations. Generally, one long bone (e.g.,
417 femur) measured for length at necropsy is sufficient (Note 4).

418 **3.8.1.3 Food Consumption**

419 Food consumption during the postweaning period should be assessed as appropriate for the
420 species.

421 **3.8.1.4 Sexual Development**

422 The physical indicators of onset of puberty (e.g., for rodents, the age of vaginal opening in
423 females and balanopreputial separation in males) are recommended when the treatment period
424 encompasses the relevant developmental window.

425 **3.8.1.5 Clinical Pathology**

426 Standard clinical pathology examinations (serum chemistry and haematology) should be assessed
427 as a terminal endpoint at necropsy if evaluation is planned at an age in which expected clinical
428 pathology ranges are known and can support interpretation of histopathology findings.

429 **3.8.1.6 Anatomic Pathology**

430 At the end of the treatment and/or off-treatment periods, gross pathology, organ weights (Note
431 5), and comprehensive collection and preservation of tissues should be conducted for animals
432 allocated to necropsy. Histopathology should be performed on major organs (e.g., bone, brain,
433 ovary, testis, heart, kidney, liver) and those with macroscopic lesions. Testicular
434 histopathology should include a qualitative evaluation of spermatogenic progression in mature
435 animals.

436 **3.8.1.7 Toxicokinetics**

437 TK sampling should be conducted near the beginning and end of the dosing period. If dosing
438 is started preweaning, interim TK assessment(s) should be considered. A preliminary or DRF
439 JAS with TK assessment, which is recommended (see Section 3.2), will inform on the sampling
440 day and the timepoints of sample collection.

441 When designing the TK component of a JAS, microsampling and sparse sampling (if justified)
442 are strongly encouraged (see ICH S3) from the view of 3Rs.

443 For protein therapeutics, samples for anti-drug antibodies should be collected and evaluated if
 444 appropriate (see ICH S6).

445 **3.8.2 Additional Endpoints to Address Identified Concerns**

446 **3.8.2.1 Growth**

447 As appropriate for the species, crown rump length, body length (e.g., nose/tail), and/or withers
 448 height can be used as an indicator of growth. Serial non-invasive measurement of long bone
 449 length using ultrasonic echo or X-ray can be appropriate in non-rodents in addition to a direct
 450 measurement at necropsy.

451 **3.8.2.2 Skeletal Examinations**

452 When there is an identified concern about bone metabolism or structure, the measurements of
 453 bone-related biomarkers and/or expanded histopathology (e.g., histomorphometry) should be
 454 considered. Assessment of bone mineral density (e.g., microdensitometry, dual energy X-ray
 455 absorptiometry, peripheral quantitative computed tomography [CT]) or bone structure (e.g.,
 456 micro CT) can also be conducted as appropriate.

457 **3.8.2.3 Clinical Pathology**

458 Additional haematology, serum chemistry, and/or biomarkers can be considered to further
 459 characterize identified concerns on target organs/tissues. Other parameters such as urinalysis
 460 or coagulation assessments can be added when warranted.

461 Samples collected throughout the study at different ages and/or a series of samples collected
 462 within a short time period (e.g., 24 to 48 hours) can also be useful.

463 Due to the limitation in obtaining adequate sample volumes from juvenile animals (especially
 464 rodents), any additional samples that may require additional animals therefore are only
 465 recommended when critical to address a concern. When sample volume constraints exist, the
 466 parameters to be measured should be selected according to a priority based on the identified
 467 concern(s).

468 **3.8.2.4 Anatomic Pathology**

469 Additional tissues/organs can be evaluated to address specific concerns. Immunohistochemical
 470 or other special staining methods for tissue sections, electron microscopy, histomorphometry, or
 471 other imaging techniques can be warranted for interpretation of some findings.

472 **3.8.2.5 Ophthalmologic Examinations**

473 When there is concern for ocular toxicity, including retina and optic nerve, assessment of ocular
 474 endpoints should be considered. Standard ophthalmological examinations (e.g., palpebral
 475 reflex, ophthalmoscopy, slit-lamp microscopy) are not a routine endpoint for JAS, because
 476 structural development of the eye is largely completed during the prenatal period in humans.

477 **3.8.2.6 CNS Assessments**

478 There are different categories of CNS assessments, such as:

- 479 • detailed clinical observations
- 480 • behavioural tests

- 481 • learning and memory tests, and
- 482 • expanded neuropathology evaluations

483 Selection of any additional CNS assessments should be based only on the particular concerns
484 identified in the WOE evaluation. In addition, the timing of these assessments should take into
485 consideration whether the results will be used to identify adverse effects due to an extension of
486 pharmacology, developmental neurotoxicity (i.e., effects that emerge or are still present after
487 cessation of treatment) or both.

488 Detailed CNS-related clinical observations document the severity and the onset and duration of
489 the clinical signs relative to dosing (e.g., hyper- or hypoactivity, tremors). These parameters
490 should be assessed when a CNS concern has been identified by the WoE evaluation and should
491 be collected during on- and off-treatment periods as appropriate.

492 Behavioural testing can include a modified Irwin test, functional observational battery (FOB),
493 assessment of locomotor activity, evaluation of coordination and reflexes, and/or acoustic startle
494 response (e.g., habituation or prepulse inhibition). These tests should be appropriate for the
495 species being tested and the timing of these assessments should be determined relative to the
496 level of maturity in the test species.

497 In addition, learning and memory can be evaluated by a variety of methods. Different methods
498 assess different aspects of learning and memory. When specific aspects of learning and memory
499 have been identified as areas of concern based on the WoE evaluation, then tests capable of
500 assessing those aspects should be selected. Learning and memory should be evaluated typically
501 during the off-treatment period as this period is most relevant to assess potential persistent or
502 delayed effects. If learning and memory testing is performed during the treatment period, the
503 potential for confounding pharmacological effects (e.g., sedation, decreased motor coordination)
504 should be considered and avoided.

505 Any CNS areas or components (e.g., hippocampus, myelin) that are identified by the WoE
506 evaluation as potential targets of concern should be assessed with additional neuropathological
507 examinations as appropriate (e.g., additional levels for sections, immunohistochemistry, special
508 stains). These assessments are typically performed at times of scheduled necropsy, unless there
509 is a specific concern related to timing to be investigated. Imaging technologies may also be
510 useful in specific circumstances (e.g., magnetic resonance imaging).

511 Postnatal CNS assessments are most commonly conducted and characterized in the rat. For
512 those pharmaceuticals where the rodent is an inappropriate species, some behavioural tests are
513 also available in other species (e.g., dogs, minipigs). Learning and memory assessments are
514 infrequently conducted in NHPs. In NHPs, behavioural observations can provide the primary
515 assessment of potential CNS effects in a JAS or ePPND study.

516 **3.8.2.7 Reproductive Assessments**

517 If there is an identified concern for effects on female and/or male reproductive organs or function,
518 histopathology examinations and organ weights can be expanded to include reproductive and/or
519 endocrine tissues in addition to the gonads. Reproductive system effects identified as irreversible
520 in adult animals need not be confirmed in a JAS.

521 In rodents, for concerns relevant for females, assessment of estrous cyclicity is recommended as
 522 an initial assessment of reproductive and endocrine function. For concerns relevant for male
 523 rodents, sperm analysis (e.g., counts, motility, morphology) and/or testicular
 524 immunohistochemistry can be considered to further characterize effects if they can add critical
 525 information not already captured elsewhere.

526 The timing of the treatment and assessments in relation to that of sexual maturation in the species
 527 tested is critical. The timing of folliculogenesis and spermatogenesis should be considered in
 528 the study design and timing of reproductive assessments. Assessment of reproductive organs
 529 or function (e.g., estrous cyclicity, sperm count, or qualitative histologic assessment of
 530 spermatogenesis) can only be conducted in sexually mature animals. If the clinical age range
 531 is prepubertal, the concern is whether treatment of a medicine with reproductive toxic potential
 532 would cause any delayed effect on sexual maturation or reproductive function in adulthood. In
 533 this situation, a study should be designed to treat only during immaturity, and then allow the
 534 animal to mature without treatment, and conduct assessments after maturation is reached.

535 Mating assessments are not generally recommended in JAS. In male rodents, mating
 536 assessments have low sensitivity due to a large functional reserve of the testis. In female rodents,
 537 assessment of estrous cyclicity and ovarian histology can identify many developmental
 538 reproductive liabilities. In non-rodent species mating assessments are not practical due to the
 539 protracted duration of development and high degree of individual variability.

540 The feasibility of other additional reproductive assessments is such that the large majority are
 541 conducted in rodents, although they can be considered for those nonrodent species that achieve
 542 maturity during the conduct of a JAS. In NHP, additional reproductive assessments are not
 543 typically included in JAS.

544 Hormonal assessments are only recommended in JAS if they can add critical information not
 545 already captured elsewhere as there is considerable hormonal variability during puberty. Any
 546 hormone assessment should be justified, and the timing and specific hormones assessed should
 547 be well characterized for the age the assessment occurs.

548 **3.8.2.8 Immunologic Assessments**

549 If the pharmacological class or data in animals or humans give cause for concern for the
 550 development of the immune system, assessments for immunotoxicity should be considered as
 551 outlined in ICH S8. Such concerns can include, but are not limited to, a transient, prolonged or
 552 permanent decrease or increase in the number or function of a lymphocyte subtype or a sustained
 553 increase or decrease in immunoglobulin class. Functional assays such as the TDAR should be
 554 performed after appropriate times of development (e.g., after PND 45 for the rat).

555 **3.8.2.9 Other Possible Assessments**

556 If there are additional tissues or endpoints for which concerns are identified and cannot be
 557 managed clinically, appropriate evaluations should be planned and performed when nonclinical
 558 investigations can add useful information.

559 3.9 Allocation of Animals to Study Groups**560 3.9.1 Prewaning Allocation**

561 In most species, initiation of a JAS during the preweaning phase presents a unique situation of
562 dosing offspring within a litter. The maternal animal is a critical component of the study
563 providing nutrition and care, but only the offspring are the test system. The study should be
564 designed to reduce potential confounders of data from offspring related to genetics, maternal care,
565 and littermates (i.e., nature and nurture confounders). Generally, genetic siblings and/or
566 littermates should not be assigned to the same endpoints, especially for the core study
567 endpoints. This can be achieved by the way the litters are constructed in combination with how
568 they are assigned to dose groups and subsets of endpoints.

569 It is advisable to utilize litter sizes and sex ratios reasonably similar to the natural mean litter
570 sizes for that species and strain. As for the method of assigning dose groups, it is desirable to
571 prevent animals in a control group from being exposed to the test pharmaceutical, thus is it
572 preferred that all animals in a litter be assigned to the same treatment group.

573 JAS can become large and complex, therefore it is especially important that the study design
574 balances scientific rigor against animal use. Investigators should know all the planned endpoints
575 (core and additional) to design the littering and subset assignment strategy
576 efficiently. Efficiency in study design is critical to reduce animal use as per the 3R principles,
577 and should be measured by the number of maternal animals and litters needed to supply the
578 study. For animal species with low and variable litter sizes or single offspring, the same
579 approach for group allocation design as in general toxicity studies can be appropriate.

580
581 After the study has started, each litter size should remain comparable across and within dose
582 groups, as much as possible, while in the preweaning phase because litter size affects pup growth
583 rate. Litter handling, dose group and endpoint subset allocation methods, and specifics of the
584 testing model (e.g., age when litters culled, litter size and sex distribution, fostering, assignment
585 of groups and subsets for evaluation) should be clearly described in the study plan and
586 report. For statistical analysis, data collected from offspring while part of a litter should not be
587 considered an independent variable since an individual offspring is dependent on maternal and
588 littermate factors.

589 There are different allocation methods for litter management in preweaning, multiparous
590 animals. Appendix C provides one example of an approach for rodents that controls for potential
591 genetic, maternal care, and littermate biases. Other methods are acceptable if they appropriately
592 consider these biases and the study objectives.

593 3.9.2 Postweaning Allocation

594 In multiparous animal species, if possible, it is still recommended to allocate the litters to
595 minimize the genetic bias and maternal and littermate variables. In particular when dosing starts
596 in the early postweaning phase, and, when offspring are supplied from a limited number of natural
597 mothers in the test facility, the study should be designed in consideration of the potential
598 confounders similar to those at preweaning allocation.

599 **3.10 Animal Numbers and Sex**

600 A JAS should use an adequate number of animals to evaluate the selected endpoints (e.g., body
601 weights, reversibility, behavioural assessments). To reduce the number of animals, combining
602 assessment of endpoints in the same animals can be effective. It is recommended that JAS be
603 performed in both female and male animals.

604 **4 CONSIDERATIONS FOR PAEDIATRIC-FIRST/ONLY DEVELOPMENT**

605 Section 3 should be consulted to determine study designs needed to address the points below.

606 A common clinical approach for non-oncology paediatric-only/first pharmaceuticals starts with
607 a First in Human (FIH) study in healthy adult volunteers prior to any paediatric trial. As per
608 ICH M3, this approach generally includes nonclinical repeat-dose toxicity studies of appropriate
609 duration in rodent and non-rodent animals as well as safety pharmacology and genetic toxicology
610 studies before initiation of adult clinical trials. Principles of ICH S6 can also apply. The
611 repeat-dose toxicity studies to support FIH in adults could be performed in several ways; in both
612 species in adult animals or in one or both species by initiating dosing in juvenile animals and
613 continuing treatment into maturity including additional endpoints (see Sections 2 and 3).

614 Alternatively, there are cases where paediatric patients are treated without any prior adult patient
615 or healthy volunteer data (e.g., for a life-threatening or debilitating disease that only exists in
616 children and when the pharmaceutical cannot be given safely to adult volunteers). In these cases,
617 the FIH trial will be in paediatric patients and the nonclinical program would generally include
618 one JAS in a rodent and one JAS in a non-rodent species, if feasible. Safety pharmacology and
619 genotoxicity testing would be conducted as appropriate for adult use; *in vivo* studies need not be
620 conducted in juvenile animals (see Section 2.3.4).

621 After initial clinical trials, JAS can be important to support continued clinical development in
622 paediatric patients on a case-by-case basis, driven by cause for safety concern (see Section 2) and
623 duration of clinical treatment. The principles of ICH M3 should also be considered. If the
624 pharmaceutical is intended to treat a chronic disease, chronic toxicity studies should be conducted
625 in one rodent and one non-rodent species. In at least one of these studies, dosing should start at
626 an age developmentally matched to the lowest age of the intended patient population. In
627 principle, a single set of chronic studies that start dosing from ages that developmentally correlate
628 to the youngest paediatric patient age can provide nonclinical safety data sufficient to cover all
629 ages and durations of paediatric development up to marketing, and can replace adult chronic and
630 separate JAS. Further nonclinical assessments of reproductive toxicity and carcinogenic
631 potential can be warranted.

632 For biopharmaceuticals, studies in juvenile animals should be limited to relevant species, as per
633 ICH S6. When the NHP is the only relevant species, a JAS in NHPs could support initial
634 clinical use. Non-invasive safety pharmacology endpoints can be included in the juvenile or
635 standard NHP repeated-dose studies. Genotoxic and carcinogenic potential should be
636 addressed as outlined in ICH S6.

637 JAS in NHP are typically conducted starting at 10-12 months of age, thus limiting the lowest
638 paediatric age ranges. In cases where JAS is not feasible to support the youngest paediatric age,

639 alternative approaches (e.g., in vitro assays, genetically-modified animals, surrogate molecules)
640 should be considered if available and relevant.

641 A JAS in perinatal and preweaning NHP should only be conducted in the situation of medicines
642 with first and primarily neonatal clinical use, and where alternative approaches to nonclinical
643 safety assessment are not feasible. Studies with direct dosing of offspring can require large
644 numbers of mature dams to populate even a relatively small JAS in NHP. Therefore the design
645 and endpoints should be clearly justified based on the clinical concern. Design expectations
646 should also be flexible; for example, variability in gender distribution and starting weights are
647 expected.

648 **5. OTHER CONSIDERATIONS**

649 **5.1 Excipients**

650 Dedicated JAS on excipients are generally not needed to qualify paediatric formulations. To
651 assess the safety of the paediatric clinical formulation, available toxicity information on the
652 excipients should be evaluated. Pharmaceutical formulations used in paediatric indications can
653 occasionally contain novel excipients or excipients not previously used in paediatric populations
654 of a relevant age. If there are insufficient data to support the use of the excipient in the intended
655 paediatric population, a JAS can be warranted. Although JAS that are primarily intended to
656 assess the safety of active ingredients need not always be conducted with the clinical formulation,
657 an excipient could be assessed in a JAS along with the active ingredient, if such studies were
658 being conducted.

659 **5.2 Combination Pharmaceuticals**

660 The development of combination pharmaceuticals for paediatric use should have a nonclinical
661 evaluation consistent with the principles outlined in ICH M3 (R2) for combination products in
662 general together with the WoE principles outlined in this guideline. For example, a combination
663 JAS would generally not be recommended for a combination of two late stage entities for which
664 there is adequate paediatric clinical experience with co-administration. Whereas, a combination
665 JAS might be warranted for a combination of two early stage entities if a WoE evaluation
666 suggests that a JAS would address identified concerns. If additional nonclinical information is
667 needed, the study design should consider what assessment endpoints are appropriate to address
668 any concerns of administering the particular combination. If a JAS is considered appropriate,
669 assessment of the combination as it is to be used clinically is generally sufficient and testing of
670 the individual active ingredients may not be critical. Alternatively, an extra group with the
671 combination could be added to a JAS that is already being conducted with one of the single
672 entities. This could eliminate the need to do a separate study with the combination product.

673 **GLOSSARY**

674 **Enhanced Pre- and Postnatal Development Study (ePPND):**

675 This study design is based on biopharmaceutical (NHP) experience and is a PPND study which
676 includes elements of the embryofetal development (EFD) study in newborns and infants instead
677 of the fetus.

678

679 **Juvenile:**

680 Any postnatal stage not fully matured in terms of morphology and function

681

682 **Paediatric First:**

683 Paediatric-first development is when the pharmaceutical is developed for paediatric patients
684 before any clinical data are available in adults for any indication.

685

686 **Paediatric Only:**

687 Paediatric-only development describes development for an indication requiring treatment
688 exclusively in paediatric ages (e.g., neonatal respiratory distress syndrome).

689

690 **Weight of Evidence:**

691 An approach that evaluates a combination of information from several independent sources to
692 determine if there is sufficient evidence to support paediatric clinical trials or whether
693 additional nonclinical assessments are recommended to address safety concerns that cannot be
694 managed clinically.

695 The weight given to the available evidence depends on factors such as the quality of the data,
696 consistency of results, nature and severity of effects, and relevance of the information. The
697 weight of evidence approach requires use of scientific judgment and, therefore, should consider
698 the robustness and reliability of the different data sources.

699 **NOTES**

- 700 Note 1 If the off treatment period begins prior to maturity, the capacity and character of the
 701 recovery can be influenced by the continued growth and development of some organ
 702 systems, and should be carefully interpreted.
 703
- 704 Note 2 The propensity for mortality to occur is generally higher in juvenile animals compared
 705 to adult animals. Study-related procedures should be limited as much as possible
 706 before and at the time of weaning as they can contribute to mortality.
 707
- 708 Note 3 Assessments on immature animals should be done with reference to age-matched
 709 control data (e.g. body weights, clinical pathology, organ weights, histology) either
 710 from concurrent control animals or from other reference background data. This is
 711 especially important to consider in cases of unscheduled assessment of endpoints.
 712 JAS animals are generally not screened prior to initiation of treatment. Therefore,
 713 background rates of abnormalities in juveniles can differ from animals of the same age
 714 used in adult toxicity studies.
 715
- 716 Note 4 Since growth happens in spurts, frequent assessments of bone length for ‘transient’
 717 effects on growth is challenging to appropriately power and offers limited value. An
 718 assessment using data from the end of treatment is more useful. An effect solely on
 719 decreased body weight gain is not necessarily an effect on growth.
 720
- 721 Note 5 Assessment of organ weight data should be done in the context of growth. For
 722 instance, if growth was restricted then absolute weights of most organs decrease in
 723 proportion to body weight; however, some organs have different sensitivity to growth
 724 effects.

725 **REFERENCES**

- 726 1. ICH E11 Guideline: Clinical Investigation of Medicinal Products in the Paediatric
727 Population; 2017
- 728 2. ICH M3 Guideline: Guidance on Nonclinical Safety Studies for the Conduct of
729 Human Clinical Trials and Marketing Authorization for Pharmaceuticals; June
730 2009.
- 731 3. ICH S5 Guideline: Detection of Toxicity to Reproduction for Medicinal Products
732 and Toxicity to Male Fertility; 2000
- 733 4. ICH S6 Guideline: Preclinical Safety Evaluation of Biotechnology-Derived
734 Pharmaceuticals; 2011
- 735 5. ICH S9 Guideline: Nonclinical Evaluation for Anticancer Pharmaceuticals; 2009

736 **APPENDIX A: OVERVIEW OF AGE-DEPENDENT DEVELOPMENT OF ORGAN SYSTEMS BY SPECIES**

737 These tables reflect a high level overview of organ system development by species to illustrate similarities and differences between the
738 commonly used toxicology species, as compared to humans, for the timing and relative duration of development. Specific milestones include
739 birth, introduction of solid foods, weaning, puberty, and adulthood. The tables are intended to aid in the assessment of the relevance of
740 existing nonclinical data, as well as the selection of species, starting age, and dosing duration for a JAS. These summary tables are based on
741 a review of current knowledge, but are not comprehensive. Species-specific and/or organ system reviews in the literature can provide
742 additional detail and should be consulted for each specific situation.

743 APPENDIX A: OVERVIEW OF AGE-DEPENDENT DEVELOPMENT OF ORGAN SYSTEMS BY SPECIES

744

745 Figure A.1: Age-dependent Development of Human Organ Systems

746

System	General Considerations	Neonate (< 1 mths)	1 st Solid Food (~ 6 mths)	Weaning Toddler (~ 2 years)	Puberty (~ 11-15 years)	Adulthood (> 18 years)
Integument	<ul style="list-style-type: none"> Critical neonatal function (barrier, water and thermoregulation, conductance, sensation) then progressive surface acidification, local microbiome and immune function 					
CV	<ul style="list-style-type: none"> Critical neonatal physiologic transitions (pulmonary and systemic vascular resistance) Adaptive myocardial and vascular changes Progressive increase in ion channels. 					
GI	<ul style="list-style-type: none"> Functional at birth, with adaptations especially over first year to accommodate shift in diet/complexity and populate microbiome 					
Renal	<ul style="list-style-type: none"> Nephrogenesis complete at term birth Progressive increase in GFR and renal function over first year 					
Hepato-biliary	<ul style="list-style-type: none"> Structurally well developed at birth Progressive increase in metabolic functionality, especially over first 6 months to 1 year of age 					
Pulmonary	<ul style="list-style-type: none"> Increased alveolization and surface area over first year 					
Immune	<ul style="list-style-type: none"> Progressive population of secondary immune tissues and development of memory as a function of time and environment 					
Endocrine	<ul style="list-style-type: none"> Most glands are well developed at birth and critical for growth Zona reticularis of adrenal cortex and gonads undergo expansion in late childhood/early puberty 					
Reproductive	<ul style="list-style-type: none"> Testes descended at birth, populated by germ cells, Sertoli cells and Leydig cells 'Mini puberty' at 2 to 4 months of age, adrenarche in late childhood Subsequent reproductive changes occur at onset of puberty and continue until adulthood 					
Nervous	<ul style="list-style-type: none"> Defined sequential and progressive development into adulthood Maximum neuron count and brain:body weight at birth, with postnatal apoptosis, pruning and migration Myelin and glia present at birth Neurotransmitter and conduction systems mature at variable rates (ie: opiate receptors/metabolism, GABA, serotonin & noradrenalin differ) 					
Skeletal	<ul style="list-style-type: none"> Growth plates present at birth most rapid postnatal growth occurs prior to age of 4 years, with slower growth through childhood primarily mediated by GH and TH pubertal growth spurt driven by sex hormones growth plates close during adolescence/early adulthood 					

747

748

	Major period of functional and structural growth and development
	Completion of structural development; active period of growth and/or functional maturation
	Slow continued growth or refinement of function; also can reflect a period of relative inactivity, as in prepubertal reproductive tissues
	Structurally and functionally fully mature

749

750 Figure A.2: Age-dependent Development of Rat Organ Systems

751

System	General Considerations	Neonate (~ PND 1-10)	1 st Solid Food (~ PND 15)	Weaning (~ PND 21-25)	Puberty (M ~ PND 42, F ~ PND 35)	Adulthood (~ PND 70)
Integument	<ul style="list-style-type: none"> Critical neonatal function (barrier, water and thermoregulation, conductance, sensation) Thicker epidermis first 2 weeks of age Adnexa and hair develop postnatally Structurally resembles adult by PND 21 sexual dimorphism by PND 35 to 42 					
CV	<ul style="list-style-type: none"> Critical neonatal physiologic transitions (pulmonary and systemic vascular resistance) Adaptive myocardial and vascular changes Progressive increase in cardiomyocytes and ion channels to PND 21 					
GI	<ul style="list-style-type: none"> Immature at birth; lack gastric acid and poor pancreatic enzyme production until after PND 14 Highly permeable proximal small intestine allows absorption of intact proteins Adaptations in 3rd week postnatal to accommodate shift in diet 					
Renal	<ul style="list-style-type: none"> Nephrogenesis incomplete at birth Progressive increase in GFR and renal function over first 3 to 5 weeks of age 					
Hepato-biliary	<ul style="list-style-type: none"> Structurally immature at birth Progressive development of organized hepatic cords and plates, with increase in metabolic functionality, over first 4 weeks of age 					
Pulmonary	<ul style="list-style-type: none"> Saccular at birth alveolization occurs over first 2 to 3 weeks of age 					
Immune	<ul style="list-style-type: none"> Progressive population of secondary immune tissues and development of memory as a function of time and environment TDAR typically assessed after PND 45 					
Endocrine	<ul style="list-style-type: none"> Most glands are well developed at birth and critical for growth 					
Reproductive	<ul style="list-style-type: none"> Period of decreased androgen production by Leydig cells during 3rd week postnatal necessary for expansion of germ cells and Sertoli cells Remaining reproductive changes and appearance of sexual dimorphism occur at onset of puberty (postnatal week 5 to 7) 					
Nervous	<ul style="list-style-type: none"> Structural maturation of olfactory bulbs, retina/eye, cerebellum, hippocampus, and cerebral cortex occurs postnatally Maximum neuron count and brain:body weight at PND7, with extensive postnatal apoptosis, pruning and migration Myelin not present at birth Conduction systems, opiate receptors/metabolism, GABA, serotonin & noradrenalin pathways mature at different rates 					
Skeletal	<ul style="list-style-type: none"> Rapid postnatal growth through adulthood Long bone growth plate structure not evident until PND 14 to 21, and remain open into adulthood 					

752
753

	Major period of functional and structural growth and development
	Completion of structural development; active period of growth and/or functional maturation
	Slow continued growth or refinement of function; also can reflect a period of relative inactivity, as in prepubertal reproductive tissues
	Structurally and functionally fully mature

754
755

Figure A.3: Age-dependent Development of Beagle Dog Organ Systems

ICH S11 Guideline

System	General Considerations	Neonate (< 3 wks)	1st Solid Food (~ 3 wks)	Weaning (~ 8 wks)	Puberty (M ~ 5-8 mths, F ~ 6-12 mths)	Adulthood (> ~ 12 mths)
CV	<ul style="list-style-type: none"> Critical neonatal physiologic transitions (pulmonary and systemic vascular resistance) Adaptive myocardial and vascular changes Cardiac innervation continues development during approx. 2 to 4 months of age Significant increase in blood pressure and decrease in heart rate from week 1 to 6 months of age 					
GI	<ul style="list-style-type: none"> Similarities in the stomach to that seen in human At birth gastrointestinal tract is fully formed (functional development primarily between birth and weaning) 					
Renal	<ul style="list-style-type: none"> Kidney is structurally and functionally immature at birth Completion of nephrogenesis at approx. 2 weeks of age Acid-base homeostasis develops postnatally Concentrating ability develops prenatally 					
Hepato-biliary	<ul style="list-style-type: none"> Hepatic structural maturation reached at approx. one week of age Bile secretory function not fully mature at birth (at 4 to 6 weeks of age: 30 to 70 % of adult values) 					
Pulmonary	<ul style="list-style-type: none"> Considered acceptable model for the study of pulmonary toxicity in juvenile population 					
Immune	<ul style="list-style-type: none"> Immunologic tissues are largely structurally mature at or shortly after birth Development of the immune system very similar to that seen in human, but placental transfer of IgG is poor IgG transfer from dam primarily occurs during first 24 h postnatally via the colostrum thymus undergoes rapid postnatal growth and reaches maximum size at 1 to 2 months of age 					
Reproductive	<ul style="list-style-type: none"> Testicular descent incomplete at birth: occurring at 5 to 6 weeks of age Males reach sexual maturity at approx. 7 to 8 months of age Females reach sexual maturity at approx. 8 to 12 months of age 					
Nervous	<ul style="list-style-type: none"> Rapid cognitive development through 12 to 16 weeks of age with critical developmental period for learning at approx. PND 18 to 28 Neonatal (primitive) reflexes also disappear at approx. PND 28 Functional locomotor development occurs postnatally (standing approx. 3 weeks of age with rapid progression through first month) 					
Skeletal	<ul style="list-style-type: none"> Long bone ossification primarily occurs postnatally with appearance of ossification centers between 1 to 10 weeks of age Most rapid long bone growth is complete by 5 months of age, with slower continued growth through puberty 					

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	Major period of functional and structural growth and development
	Completion of structural development; active period of growth and/or functional maturation
	Slow continued growth or refinement of function; also can reflect a period of relative inactivity, as in prepubertal reproductive tissues
	Structurally and functionally fully mature

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Figure A.4: Age-dependent Development of Göttingen Minipig Organ Systems

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System	General Considerations	Neonate (< 2 wks)	1 st Solid Food (~ 2 wks)	Weaning (~ 4 wks)	Puberty (M ~ 3/4 mths, F ~ 4/5 mths)	Adulthood (> ~ 6 mths)
Integument	<ul style="list-style-type: none"> Critical neonatal function (barrier, water and thermoregulation, conductance, sensation) similarities in development to human 					
CV	<ul style="list-style-type: none"> Critical neonatal physiologic transitions (pulmonary and systemic vascular resistance); Adaptive myocardial and vascular changes Similarities in development to human 					
GI	<ul style="list-style-type: none"> Maturity reached by approx. 4 weeks of age Model for human stomach development 					
Renal	<ul style="list-style-type: none"> Nephron formation up to approx. 3 weeks after birth Functional mature at approx. 3 months of age 					
Hepato-biliary	<ul style="list-style-type: none"> Structurally and functionally immature at birth Adult appearance at approx. 4 weeks of age and full function at 3 to 4 months of age 					
Pulmonary	<ul style="list-style-type: none"> Lungs are well developed at birth Alveolization occurs over first 1 to 2 weeks of age and completed within 2 weeks of age 					
Immune	<ul style="list-style-type: none"> Very little function at birth Anatomically full developed at approx. 4 weeks of age Model for human immune development 					
Reproductive	<ul style="list-style-type: none"> Sexual maturity in males with approx. 3 to 4 months of age and in females with approx. 4 to 5 months of age 					
Nervous	<ul style="list-style-type: none"> Growth mainly in the late prenatal to early postnatal period Nervous system complete by 6 months of age Brain development of the neonatal pig is similar to the human term neonate Neuromuscular system is more functionally mature at birth than in human 					
Skeletal	<ul style="list-style-type: none"> Rapid postnatal growth through adulthood; closure of the epiphysial growth plates at 18 months of age Full grown adults at approx. 24 months 					

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	Major period of functional and structural growth and development
	Completion of structural development; active period of growth and/or functional maturation
	Slow continued growth or refinement of function; also can reflect a period of relative inactivity, as in prepubertal reproductive tissues
	Structurally and functionally fully mature

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Figure A.5: Age-dependent Development of Cynomolgus Monkey Organ Systems

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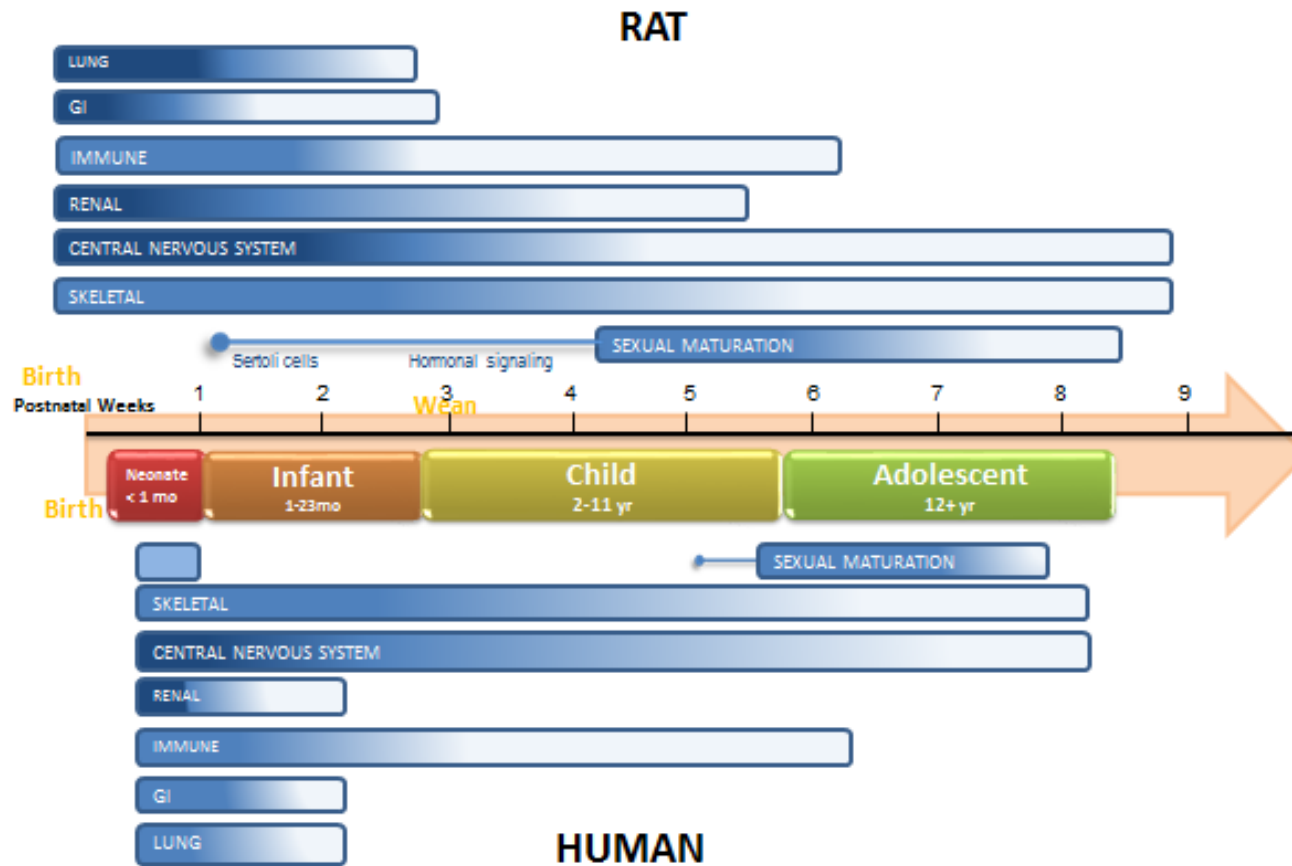
System	General Considerations	Neonate (< 1 mth)	1 st Solid Food (~ 3 mths)	Weaning (~ 6 mths)	Puberty (~ 3-4 years)	Adulthood (~ 4 years)
Integument	<ul style="list-style-type: none"> Functional (barrier, water and thermoregulation, conductance, sensation) with hair and adnexa present at birth 					
CV	<ul style="list-style-type: none"> Critical neonatal physiologic transitions (pulmonary and systemic vascular resistance) Adaptive myocardial and vascular changes Myocardocyte expansion through 3 months of age, then progressive growth 					
GI	<ul style="list-style-type: none"> Functional at birth, with adaptations especially over first year to accommodate shift in diet/complexity and populate microbiome 					
Renal	<ul style="list-style-type: none"> Nephrogenesis complete at term birth Progressive increase in GFR and renal function over first 6 months of age 					
Hepato-biliary	<ul style="list-style-type: none"> Structurally well developed at birth; progressive increase in metabolic functionality, especially over first 3 to 6 months 					
Pulmonary	<ul style="list-style-type: none"> Structurally mature at birth with progressive growth 					
Immune	<ul style="list-style-type: none"> Progressive population of secondary immune tissues and development of memory as a function of time and environment 					
Endocrine	<ul style="list-style-type: none"> Most glands are well developed at birth and critical for growth Zona reticularis of adrenal cortex expands at 3 to 6 months of age (adrenarche) endocrine function of gonads expands at puberty 					
Reproductive	<ul style="list-style-type: none"> Testes descended at birth, populated by germ cells, Sertoli cells and Leydig cells Follicular development and atresia begins at 3 to 6 months Subsequent reproductive changes (menarche and spermarche) occur in at onset of puberty and continue until adulthood 					
Nervous	<ul style="list-style-type: none"> Defined sequential and progressive development into adulthood Postnatal apoptosis, pruning and migration most prominent before weaning Myelin and glia present at birth Neurotransmitter and conduction systems mature at variable rates (i.e.: serotonin and noradrenalin differ) 					
Skeletal	<ul style="list-style-type: none"> Growth plates present at birth Most rapid postnatal growth occurs prior to weaning, followed by slower growth until growth plates close during adulthood 					

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	Major period of functional and structural growth and development
	Completion of structural development; active period of growth and/or functional maturation
	Slow continued growth or refinement of function; also can reflect a period of relative inactivity, as in prepubertal reproductive tissues
	Structurally and functionally fully mature

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Figure A.6. Comparison of Rat and Human Ontogeny



770 **Table A1. Principal Advantages and Disadvantages of Various Mammalian Species for Use in Juvenile Animal Studies**

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Species	Advantages	Disadvantages
Rat	<ul style="list-style-type: none"> ● Well-studied species in juvenile animal studies with extensive historical control data ● Several consistent developmental milestones (general growth, preputial separation/vaginal opening, puberty) ● Often used for (adult) general and reproductive toxicology ● Body size allows most manipulations/administrations starting early preweaning ● Litter size allows allocation of pups to different endpoints and dedicated cohorts of pups ● Compressed development (~10 weeks) allows for inclusion of wide range of endpoints during the short period ● Compressed development allows for inclusion of endpoints which are difficult to perform using large animals (such as FOB, developmental neurotoxicity, immunotoxicity, fertility/breeding) due to longer developmental period ● Compressed development allows for inclusion of nonstandard endpoints if warranted (FOB, developmental neurotoxicity, immunotoxicity, fertility/breeding) ● Small body weight requiring low amount of test material ● Relatively easy transportation, housing and management ● Pups and dams are amenable to fostering ● Easy to obtain many pups with the same postnatal stage 	<ul style="list-style-type: none"> ● Small body size, high metabolic rate and rapid growth can lead to fast decline in general condition and death. ● Several organ systems are less developed at birth relative to man (particularly CNS, lung, kidney, GI tract and immune system; eyes do not open until PND 12-14) ● ADME characteristics of oral pharmaceuticals given in the preweaning phase often translate poorly to humans due to immaturity of the GI tract ● Compressed development can make it difficult to identify distinct windows of vulnerability ● Conventional blood samples are often terminal collections, particularly preweaning ● Can easily become very large studies as most endpoints or collections require dedicated cohorts of pups
Mouse	<ul style="list-style-type: none"> ● Generally similar to rat, some differences may make mouse a better model for specific organ systems ● Many genetic modification models available 	<p>Similar to rat, additionally:</p> <ul style="list-style-type: none"> ● Allows fewer manipulations /administrations than rat from early on ● Requires dedicated cohorts of pups for each endpoint or collection and can require sample pooling ● Less historical information than the rat.

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Species	Advantages	Disadvantages
Dog	<ul style="list-style-type: none"> ● Often used in general (adult) toxicology ● Relatively large at birth ● Relatively easy to handle ● Litter size allows allocation of pups to different endpoints ● Puppies can be separated from dams for a few hours ● Breeding can be planned in advance 	<ul style="list-style-type: none"> ● Protracted development (~7-14 months to sexual maturity, ~18-24 months to skeletal maturity) with variable developmental milestones ● Altricial at birth (i.e. eyes do not open until ~ 2 weeks postnatally) ● Variable litter sizes and sex distribution can make it difficult to populate study with minimal bias (genetic/litter, sex distribution) across groups ● Limited historical background data, especially for nonstandard endpoints ● Substantial inter-individual variability in growth and development ● Seasonal breeder (supply & study start over weeks or months) ● Not amenable to fostering ● Large body size requires comparably large amounts of test compound compared to rodents
Minipig/ Pig	<ul style="list-style-type: none"> ● Many similar developmental milestones as humans ● Relatively large at birth ● Relatively easy to handle ● Breeding can be planned in advance ● Litter size allows allocation of piglets to different endpoints ● Amenable to cross fostering ● Relatively large litters usually allow balanced sex distribution ● Neonatal GI tract similar to human for orally administered drugs ● All routes of administration feasible (except inhalation); best model for dermal studies ● Short development (~6-9 months), relatively easy transport and housing compared to other large non-rodents 	<ul style="list-style-type: none"> ● Less well established historical control data than dog or NHP toxicology species ● Require colostrum for passive transfer of maternal Ig in perinatal period ● Large body size requires comparably large amounts of test compound compared to rodents ● IV and gavage administration can be challenging in very young piglets
Species	Advantages	Disadvantages

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<p>NHP (cynomolgus; rhesus and marmoset also feasible)</p>	<ul style="list-style-type: none"> ● Many similar developmental milestones as humans ● Neonates/infants similar to human for GI tract, immune system, cardiovascular, renal and special sense (eye, ear) development ● Macaque infants are relatively large at birth ● Extensive reference data from birth available ● Often used for (adult) general and reproductive toxicology (e.g., ePPND), especially for biopharmaceuticals ● Often the most pharmacologically relevant animal model for highly targeted therapies 	<ul style="list-style-type: none"> ● Protracted development (~3-6 years for sexual maturity, ~5-8 years for skeletal maturity in macaques) makes an extensive juvenile study to cover all developmental phases not practical ● Single offspring for macaques with high inter-individual variability in growth and development ● Marmosets typically have twins and require both maternal and paternal care in preweaning phase; offspring are relatively small ● Offspring highly dependent on maternal care over first month (minimal procedural intervention recommended; pre-weaning manipulation & dosing feasible with risk of maternal rejection), and are cohoused with dam for first 3-6 months; with shipping and quarantine requirements it is rarely feasible to initiate studies in juvenile monkeys < 9 months of age ● Neonatal NHP are precocious relative to human neonates in terms of musculoskeletal, CNS, endocrine and respiratory system ● Cannot synchronize breeding (supply & study start over weeks or months for seasonal breeders such as rhesus) ● Ethical reservations (need strong rationale to justify use of juvenile NHP for toxicity testing)
<p>Rabbit</p>	<ul style="list-style-type: none"> ● Compressed development (~5-6 months) and small body size requiring comparably low amount of test material ● Relatively easy to handle ● Often used for reproductive toxicology; also can be used for ocular administration, evaluation of bone growth ● Litter size allows allocation of kits to different endpoints ● Relatively easy transport and housing 	<ul style="list-style-type: none"> ● Developmental milestones less well established than other nonrodent species ● Not routinely used / well accepted in (adult) general toxicology ● Handling young offspring can provoke cannibalism or rejection by the mother

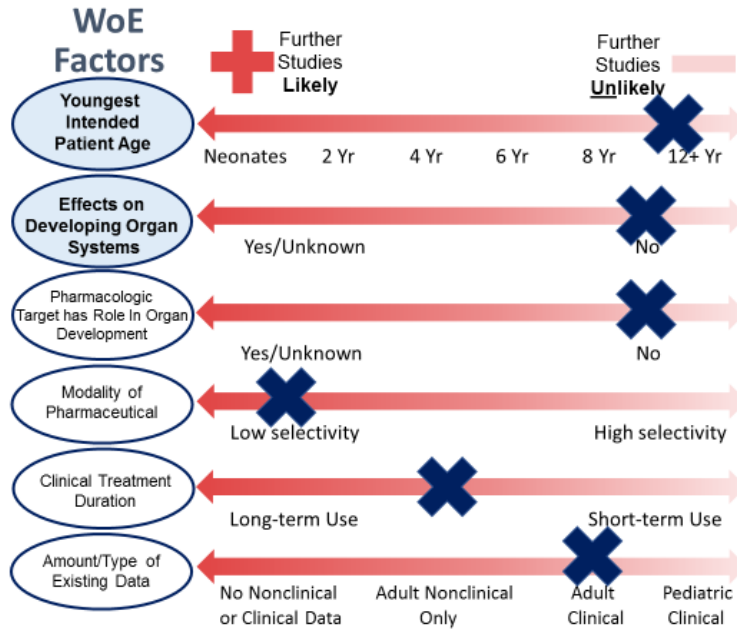
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Other Species	<p>Other species could be considered for cause when pharmacologically and toxicologically relevant. Examples of alternative mammalian test systems include the hamster, guinea pig, tree shrew, ferret, cat, sheep and goat. Advantages tend to be species and program specific, but often reflect use of that species in genetic or disease models, or when there is data supporting interpretation and translatability of specific endpoints.</p> <ul style="list-style-type: none">● Developmental milestones less well established than in rat, mouse, dog, minipig/pig and NHP● Not routinely used / well accepted in (adult) general toxicology● Limited historical control toxicology data● Limited use (model in special indications such as heart failure)● Many require colostrum for passive transfer of maternal Ig in perinatal period● Limited availability of purpose-bred animals and suitable laboratory housing
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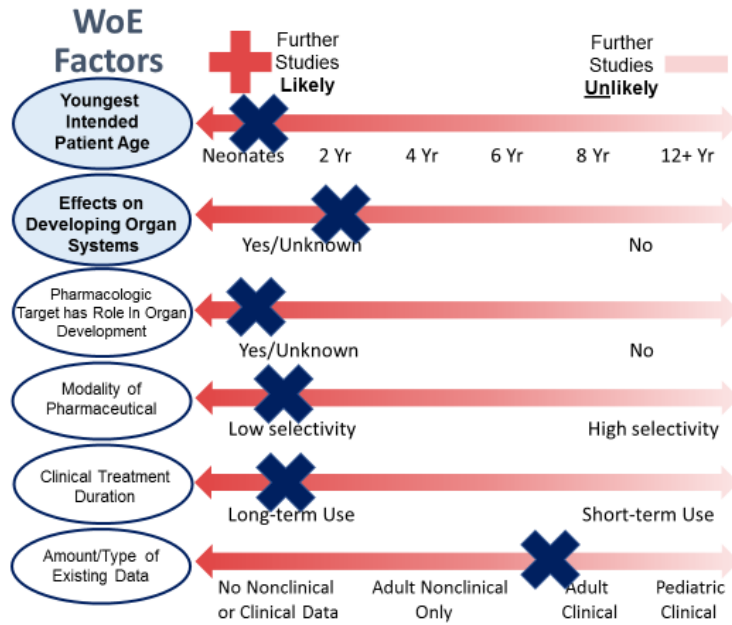
774 **APPENDIX B: CASE STUDIES APPLYING THE WEIGHT OF EVIDENCE APPROACH**

775 A. A small molecule with known pharmacology has available adult clinical and nonclinical
 776 data including repeated dose toxicity data. None of these data suggest a safety concern
 777 in a developing organ for the intended paediatric population of adolescents (12 years and
 778 above), for a one-month duration of clinical treatment. The WoE analysis indicates that
 779 no additional nonclinical investigations are needed.



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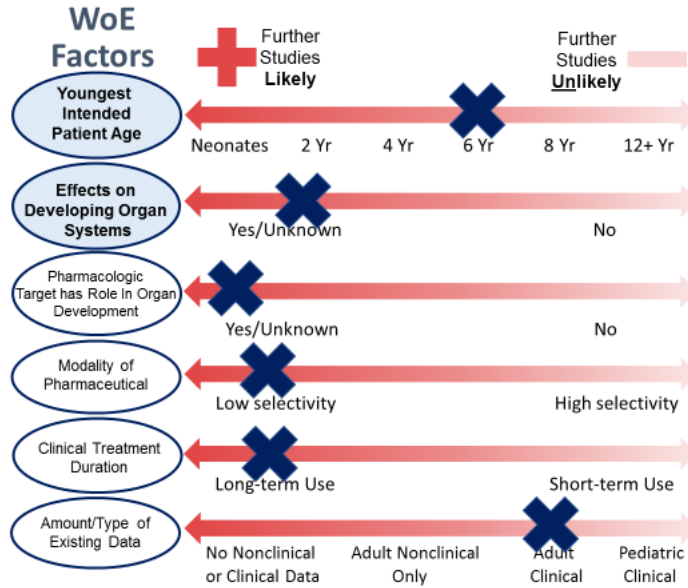
781 B. A small molecule with a novel mode of action intended for chronic use starting in
 782 neonates or infants has limited Phase 1 clinical and nonclinical safety data with no
 783 significant safety concerns identified. There are potential pharmacologic effects on
 784 developing organ systems. The WoE analysis indicates further nonclinical investigation,
 785 such as a core JAS with additional endpoints based on the targeted developing organ
 786 systems, would be useful.



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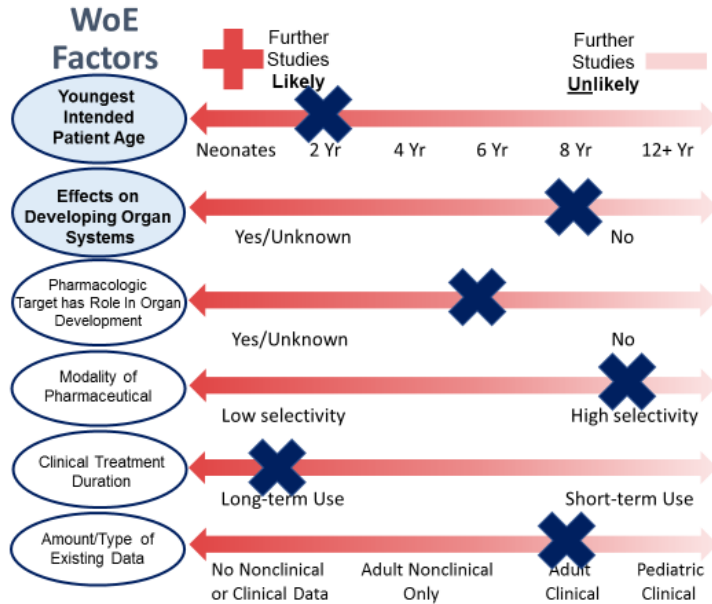
788 C. A small molecule with known pharmacology with a well characterized critical role in
 789 CNS development intended for chronic use in children (6 years and above) has
 790 nonclinical and adult clinical data. The concern for a potential effect on the developing
 791 CNS cannot be addressed clinically by monitoring and management. Existing data
 792 adequately addresses other developing systems. The WoE analysis warrants a post-
 793 weaning JAS study design that includes core endpoints and additional endpoints limited
 794 to CNS, including detailed clinical observations, behavioral assessments, a learning and
 795 memory evaluation, and expanded neuropathological examinations.

796



797

798 D. A monoclonal antibody targets a soluble cytokine and is intended for chronic paediatric
 799 use in rheumatologic and allergic diseases (>2 years old). The only findings are reversible
 800 decreased serum Ig and occasional injection site reactions (in both animals and adult
 801 patients). In a monkey ePPND study, offspring exposure was comparable to dams
 802 through PND 28 and decreased pharmaceutical Ig levels was detected on PND 28 and 56
 803 postnatally. T-cell-dependent antibody response (TDAR) results were similar to
 804 controls (between 3-6 months postnatally). The WoE analysis does not warrant a JAS.



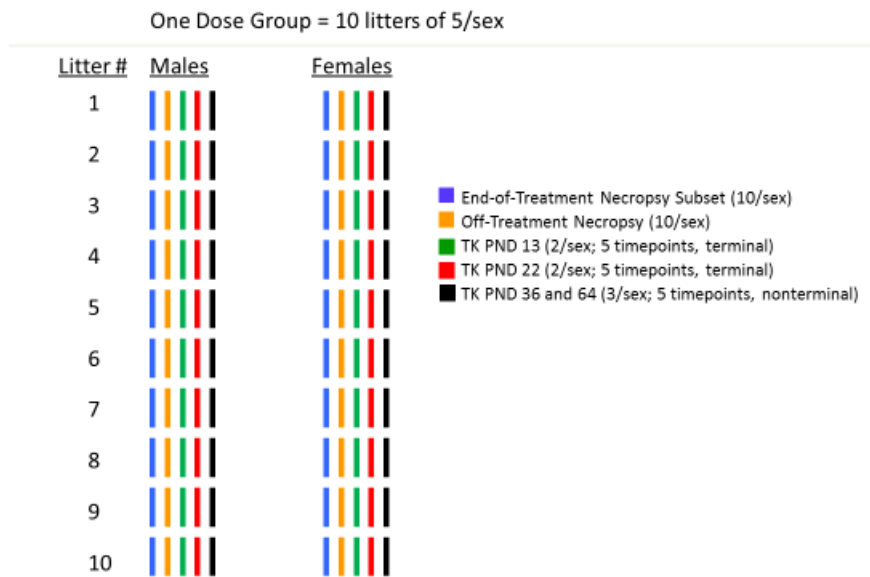
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806 **APPENDIX C: EXAMPLE OF AN APPROACH TO RODENT PREWEANING LITTER ALLOCATION:**

807 **Natural Litters + Whole Litter Group Assignment + Inter-Litter Endpoint**
 808 **Subset Assignment**

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 810 Initiation of a JAS during the preweaning phase presents a unique situation and should be
 811 designed to reduce potential confounders related to genetics, maternal care, and littermates.
 812 This is achieved by how the litters are constructed in combination with how they are assigned to
 813 dose groups, and then to subsets of endpoints. In this approach, the offspring stay with their
 814 natural mother and are culled to the desired litter size with a balanced sex ratio. When necessary
 815 to minimize the required number of litters to supply the study, a very small percentage of pups
 816 are fostered to other litters. Here, Wistar Han rat litters are culled to 10 offspring per litter
 817 composed of 5 males and 5 females (the mean natural litter size is ~11). The whole litter is then
 818 assigned to the same dose group with 10 litters each assigned to each dose group. Offspring are
 819 arbitrarily assigned to subsets for specific endpoints in an inter-litter fashion, i.e., as one male or
 820 female from each litter in a dose group to the specific endpoints. The advantage of the whole
 821 litter group assignment is the littermates receive the same dose level so there is a low risk of cross
 822 contamination and confounding variables of high dose and control offspring competing for
 823 suckling position and time. Also, keeping the pups with genetic dams and assigning the
 824 endpoints in an inter-litter fashion ensures genetic, maternal care and littermate influences are
 825 distributed evenly.

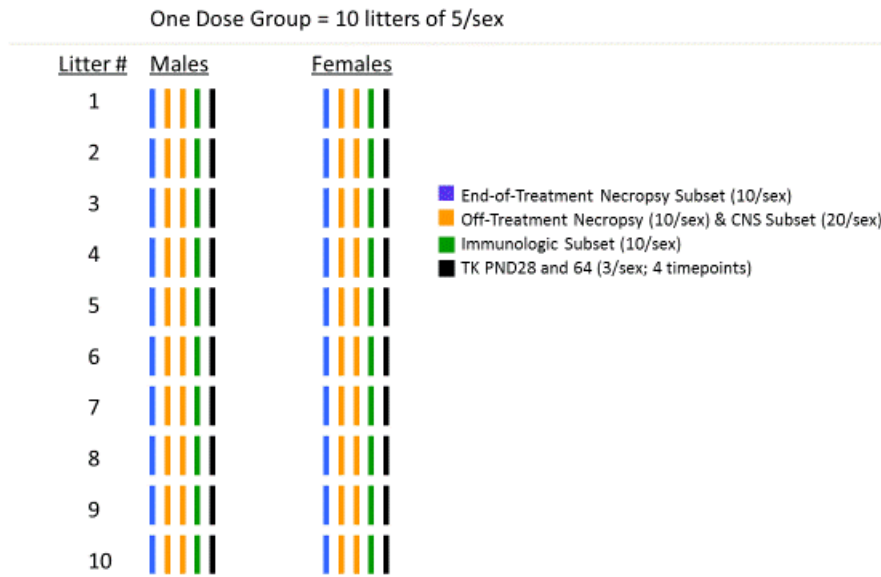
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 827 **Example A**



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 830 For Example A, the definitive JAS design includes the core assessments with the only
 831 additional assessment of off-treatment/recovery necropsy. The pups are allocated 1/sex/litter
 832 for n=10/sex for the end-of-treatment necropsy subset which would also have sexual
 833 development, clinical pathology, and long bone length. TK is collected frequently based on
 834 dose range data with two sets of 1/sex for TK on PND13 and 22 (composite terminal sampling)
 835 and 1/sex for postweaning TK collections which are nonterminal. Microsampling minimizes
 836 animal use. In this case, dosing starts on PND 7 and the first TK sampling after the first dose

837 would be collected from separate dams and litters available after randomization, because litter
 838 and maternal cofounders would not be relevant for a single dose TK assessment.

839 **Example B**



840
 841
 842 For Example B, the definitive JAS design includes the core assessments and additional
 843 assessments of off-treatment/recovery necropsy, full CNS assessments and immunologic
 844 assessment and dosing from PND 9 to 63. The pups are allocated 1/sex/litter from each litter
 845 for n=10/sex for the necropsy (with expanded neuropathology) and immunologic (TDAR)
 846 subsets each; and 2/sex for the subset for CNS testing (clinical observations, behavior and
 847 learning and memory) using half of these also for the off-dose necropsy obviating the need for
 848 extra animals, and 1/sex for postweaning toxicokinetic (serial sampling). TK sampling after
 849 the first dose would be collected from separate dams and litters available after randomization,
 850 because confounders would not be as relevant for single dose TK assessment.